UL 218

STANDARD FOR SAFETY

Fire Pump Controllers

UL Standard for Safety for Fire Pump Controllers, UL 218

Third Edition, Dated September 16, 2015

Summary of Topics

This revision of ANSI/UL 218 dated September 10, 2020 is issued to correct the recent ANSI reaffirmation date on the title page. No other changes have been made.

As noted in the Commitment for Amendments statement located on the back side of the title page, UL, CSA, and ANCE are committed to updating this harmonized standard jointly. However, the revision pages dated September 10, 2020 will not be jointly issued by UL, CSA, and ANCE as these revision pages only address UL ANSI approval dates.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

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Association of Standardization and Certification
NMX-J-626-ANCE-2015
Second Edition

CSA Group
CSA C22.2 No. 263-15
Second Edition

Underwriters Laboratories Inc.
UL 218
Third Edition

Fire Pump Controllers

September 16, 2015

(Title Page Reprinted: September 10, 2020)

Approved American National Standard

ANSI/UL 218-2015 (R2020)

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as “CSA Group”), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

ISBN 978-1-77139-927-2 © 2015 Canadian Standards Association

This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup. org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Third Edition including revisions through September 10, 2020. The most recent designation of ANSI/UL 218 as a Reaffirmed American National Standard (ANS) occurred on July 22, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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Preface

This is the harmonized ANCE, CSA Group, and UL standard for fire pump controllers. It is the second edition of NMX-J-626-ANCE, the second edition of CSA C22.2 No. 263, and the third edition of UL 218. This edition of NMX-J-626-ANCE supersedes the previous edition published on September 28, 2009. This edition of CSA C22.2 No. 263 supersedes the previous edition published in 2009. This edition of UL 218 supersedes the previous edition published in 1999.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Fire Pump Controllers, CANENA THSC 17B WG4, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican Standard was developed by the CT 64 Instalaciones eléctricas y protección contra choque eléctrico from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the fire pump controllers manufactures and users.

This standard was reviewed by the CSA Subcommittee for Fire Pump Controllers, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard was reviewed and approved by the Committee de Normalizacion of ANCE (CONANCE). This standard was reviewed by UL's Standards Technical Panel (STP) for Fire Pump Controllers, STP 218.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

Application of standard

A UL standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of harmonization

This standard uses the IEC format but is not based on, nor shall it be considered equivalent to, an IEC standard. This standard is published as an equivalent standard for ANCE, CSA, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

This standard provides requirements for fire pump controllers for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for fire pump controllers for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

INTRODUCTION

1 Scope

1.1 Products covered

1.1.1 These requirements cover controllers intended for starting and stopping centrifugal and positive displacement fire pumps, including automatic and non-automatic types for electric motor with or without transfer switch or engine driven pumps in accordance with Annex A, item 1. Types of controllers covered include diesel engine, electric motor, limited service, medium voltage and residential. Controllers may be suitable for use as service equipment. This equipment is for installation in non-hazardous locations in accordance with Annex A, item 2.

1.1.2 Controllers for electric motor driven, centrifugal fire pumps are intended for use with squirrel cage or wound rotor motors rated 600 V or less. Controllers for squirrel cage motors may be for across-the-line or reduced inrush current starting. Controllers may be provided with integral automatic transfer switches.

1.1.3 Variable speed fire pump controllers for electric motor driven, centrifugal fire pumps are intended for use with squirrel cage induction, inverter duty rated motors rated 600 V or less, and rated for 50 Hz or 60 Hz.

1.1.4 Limited service controllers are intended for across-the-line starting of squirrel cage motors rated 22 kW (30 hp) or less, 600 V or less. Controllers may be provided with integral automatic transfer switches.

1.1.5 Medium voltage fire pump controllers are intended for use with squirrel cage motors rated 601 V – 7.2 kV AC.

1.1.6 Residential fire pump controllers are intended for use with single-phase squirrel cage motors rated 240 V or less. Residential fire pump controllers are intended to be used in one or two family dwelling units in accordance with the requirements of item 35 in Annex A.

1.1.7 Diesel engine fire pump controllers rated nominal 24 V DC or less are intended for use with fire pump engines. Where required, AC voltage is limited to 600 V AC or less.

1.2 Products not covered

1.2.1 An automatic transfer switch intended to be used in fire pump circuits, that is provided separate from a controller.

Note: Stand-alone automatic transfer switches for fire pump circuits are covered by the requirements of item 11, Annex A.

2 Normative References

2.1 Products covered by this standard shall comply with the referenced installation codes and standards noted in Annex A as appropriate for the country where the product is to be used. When the product is intended for use in more than one country, the product shall comply with the installation codes and standards for all countries where it is intended to be used.

2.2 Where reference is made to any Standards, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

3 Units of Measurement

3.1 The values given in SI (metric) units shall be normative. Any other values are for information only.

4 General Requirements

4.1 General

4.1.1 In Canada, requirements applicable to this Standard are given in item 17 of Annex A.

4.2 Components

4.2.1 A component of a product covered by this standard shall comply with the requirements for that component. See Annex B for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the ANCE, CSA, or UL standards as appropriate for the country where the product is to be used.

5 Definitions

5.1 For the purpose of this standard, the following definitions apply. In Canada, in addition to the definitions listed in this standard, the definitions of item 2 in Annex A also apply.

5.2 AUXILIARY CIRCUIT – Circuits not essential for the performance of the fire pump controller.

5.3 CENTRIFUGAL PUMP – A pump in which the pressure is developed principally by the action of centrifugal force.

5.4 CIRCUIT BREAKERS

Circuit breaker (as applied to fire pump controllers) – For the purposes of this standard, the term circuit breaker (disconnecting means) refers to either thermal-magnetic or inverse time circuit breakers (for residential fire pump controllers only) or to instantaneous-only circuit breakers.

Circuit breaker – A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.[1)]

Thermal-Magnetic Circuit breaker – A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overcurrent (overload and short circuit), without damage to itself when properly applied within its rating.

Inverse Time (as applied to circuit breakers) – A qualifying term indicating that there is purposely introduced a delay in the tripping action of the circuit breaker, which delay decreases as the magnitude of the current increases.[1)]

Instantaneous-Only Circuit breaker – One intended to provide short circuit protection only.

Instantaneous Trip (as applied to circuit breakers) – A qualifying term indicating that no delay is purposely introduced in the tripping action of the circuit breaker.[1)]

[1)] 5.4, 5.6 and 5.15 originated, in part, from Article 100 of the 2011 edition of NFPA 70. Reprinted with permission from NFPA 70-2011, National Electrical Code, Copyright © 2010, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

5.5 CONTROL CIRCUIT – A circuit that carries the electric signals directing the performance of a fire pump controller, but which does not carry the main power circuit. A control circuit is generally limited to 15 A.

5.6 CONTROLLER (Electric motor) – A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.[1)]

CONTROLLER (Diesel engine) – A device or group of devices that serves to govern, in some predetermined manner, the engine power delivered to the apparatus to which it is connected.

5.7 CONTROLLER – LIMITED SERVICE – A controller that is limited in application when approved by the authority having jurisdiction, as defined in 1.1.3.

5.8 CURRENT LIMITERS – Melting link-type devices that, when used as an integral part of a circuit breaker, limit the current during a short circuit to less than the interrupting capacity of the circuit breaker.

5.9 DISCONNECTING MEANS – A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

5.10 DROP-OUT RELAY – A relay that, when de-energized, initiates the control function.

5.11 ENCLOSURE – The case or housing of apparatus constructed to provide a degree of protection against incidental contact with the enclosed equipment, and to provide a degree of protection against specified environmental conditions.

5.12 ISOLATING SWITCH – A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.

5.13 READILY ACCESSIBLE – Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.

5.14 SERVICE BOX (For Canada) – An approved assembly consisting of a metal box or enclosure constructed so that it may be effectually locked or sealed, containing either service fuses and a service switch or a circuit breaker, and of such design that either the switch or circuit breaker may be manually operated when the box is closed.

In Mexico and the United States, this definition does not apply.

5.15 SERVICE EQUIPMENT (For Mexico and the United States) – The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply.[1)]

In Canada, this definition does not apply.

5.16 SERVICE EQUIPMENT (For Canada) – In addition to 5.14, the service circuit breaker or fused switch is located in a service box.

In Mexico and the United States, this definition does not apply.

5.17 TRANSFER SWITCH (AUTOMATIC) – Self-acting equipment for transferring the connected load from one power source to another power source.[2)]

[2)] 5.17 originated from the 2013 edition of NFPA 110. Reprinted with permission from NFPA 110-2013, Standard for Emergency and Standby Power Systems, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

5.18 MEDIUM VOLTAGE – (For Mexico and the United States) An AC voltage in the range of 1501 to 7200 V.

For Canada – An AC voltage in the range of 751 to 7200 V.

Note: The applicable installation codes will in some cases refer to this voltage range as “high-voltage”.

CONSTRUCTION

6 Construction

6.1 Enclosures

6.1.1 A fire pump controller assembly shall be securely mounted in an enclosure that protects the equipment. The enclosure shall be constructed to provide strength and rigidity required to resist the abuses to which it is subjected without total or partial collapse resulting in a risk of fire, electric shock, or injury to persons due to reduction of spacings, loosening or displacing of parts, or other serious defects.

6.1.2 Enclosures for fire pump controllers shall comply with the requirements in Annex A, item 9.

6.1.3 An enclosure shall comply with the requirements for an environmental rating, excluding Type 1, as specified in Annex A, item 3.

6.2 Spacings

6.2.1 Electrical spacings through air, over surface, and between uninsulated live parts and the enclosure walls shall be at least those specified in Table 1.

6.2.2 For printed circuit wiring boards, the minimum spacings shall be as specified in Table 11.

6.2.3 The spacings at a field-wiring terminal shall be measured with wire connected to the terminal as in service. The connected wire shall be the next larger size than normally required if the terminal will accommodate it, or if the equipment is not marked to restrict its use.

6.2.4 In Mexico and the United States, the spacings specified in Table 1 for devices having limited rating shall apply to:

a) Devices rated 0.75 kW (1 hp) or less; 720 VA or less (break pilot duty); or not more than 15 A at 51 – 150 V, 10 A at 151 – 300 V, or 5 A at 301 – 600 V; or any combination thereof;

b) These same devices, when multipole and controlling more than one load, provided that the total load connected to the line at one time does not exceed 1.5 kW (2 hp), 1440 VA, or have a current rating greater than 30 A at 51 – 150 V, 20 A at 151 – 300 V, or 10 A at 301 – 600 V, and provided also that the loading on any one pole does not exceed its marked rating.

In Canada, reduced spacings for limited ratings are only allowed in control circuits.

6.2.5 In a circuit involving voltages of 50 V or less, spacings at field-wiring terminals may be 3.2 mm (0.125 inch) through air and 6.3 mm (0.25 inch) over surface.

6.2.6 In a circuit involving voltages of 50 V or less, other than field wiring terminals, the spacings shall be 1.6 mm (0.06 inch) through air or over surface, provided that the insulation and clearances between such circuits and any circuits of more than 50 V are in accordance with the requirements for the higher voltage circuit.

6.3 Insulating barriers

6.3.1 An insulating barrier or liner used as the sole separation between uninsulated live parts and grounded dead metal parts, including the enclosure, or between uninsulated live parts of opposite polarity shall be of a material specified in Table 14.

6.3.2 An insulating barrier or liner that is used in addition to not less than one-half the required spacing through air shall be of a material specified in Table 14 and shall:

a) Be of a material that is intended for the support of uninsulated live parts;

b) Have the mechanical strength required to withstand mechanical damage;

c) Be held in place; and

d) Be located so that it is not adversely affected by operation of the equipment in service.

6.3.3 Insulating barriers or liners having a thickness less than that specified in Table 14 may be used when subjected to the Barrier Dielectric Strength Test in 7.9.

6.4 Field wiring terminals

6.4.1 A controller shall be provided with wiring terminals for connection of conductors having an ampacity or wire size not less than the following:

a) For power circuits, 125 percent of the full-load motor current specified in Table 2 and Table 3 for the horsepower rating or, in the case of power conversion equipment in which the input current is different from motor full-load current, 125 percent of maximum rated input current;

b) For service use not less than 5.3 mm^2 (10 AWG); and

c) For control circuits not less than 2.1 mm^2 (14 AWG).

See Table 5 for field conductor ampacities.

6.4.2 All wiring terminals intended for field connection shall:

a) Be evaluated in accordance with Annex A, items 7 and 12, and marked for the wire size or range;

b) Be part of a device evaluated and marked for the wire size or range; or

c) Comply with the secureness and pullout requirements of 6.4.5 for the next larger size conductor than that specified in 6.4.1, unless the equipment is marked to restrict its use to only the smaller size conductor.

6.4.3 A terminal to which field wiring is to be connected shall be a pressure wire connector.

6.4.4 A terminal to which 5.3 mm^2 (10 AWG) or smaller wiring connections are to be made may consist of a clamp or wire-binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position. See 6.4.6 – 6.4.10.

6.4.5 A field-wiring pressure wire connector provided with or specified for use with industrial control equipment shall comply with one or more of the following, as applicable:

a) The performance requirements in Annex A, item 6 (see 16.12);

b) The performance requirements in Annex A, item 7; or

c) The performance requirements in Annex A, item 12.

6.4.6 A wire-binding screw to which field-wiring connections are made shall be No. 8 or larger.

6.4.7 A No. 6 screw may be used at a terminal intended only for connection of a 2.1 mm^2 (14 AWG) conductor or smaller.

6.4.8 A terminal plate tapped for wire-binding screw shall be of metal not less than 0.76 mm (0.030 inch) thick for a 2.1 mm^2 (14 AWG) or smaller wire, and not less than 1.27 mm (0.050 inch) thick for a wire larger than 2.1 mm^2 (14 AWG). There shall be at least two full threads in the plate.

6.4.9 For a terminal plate formed from stock having the required thickness specified in 6.4.8, one method of complying with the thread requirement of 6.4.8 is to have the metal extruded at the tapped hole for the binding screw to provide two full threads.

6.4.10 A wire-binding screw shall thread into metal.

6.5 Grounding

6.5.1 In Mexico and the United States, all controllers shall have provisions for grounding all non-current-carrying metal parts that are exposed or that are located in a position to be contacted by persons during normal operation or adjustment of the equipment and that are capable of becoming energized.

In Canada, this requirement does not apply.

6.5.2 In Canada, the requirements for bonding as specified in Annex A, item 19, shall apply.

In Mexico and the United states these requirements do not apply.

6.5.3 The grounding and bonding terminology used in this standard is in accordance with the UL column in Figure 1. The corresponding CEC and ANCE terms are also provided.

6.5.4 Controllers shall be provided with a terminal or an equivalent means for connecting an equipment grounding or bonding conductor except as provided in 6.5.6. A terminal shall be sized for a grounding or bonding conductor as specified in Table 7.

6.5.5 In Canada, the following requirements amend Table 7:

a) The use of aluminum wire shall not be permitted;

b) The values in brackets [xx] for size of equipment grounding or bonding conductor shall apply; and

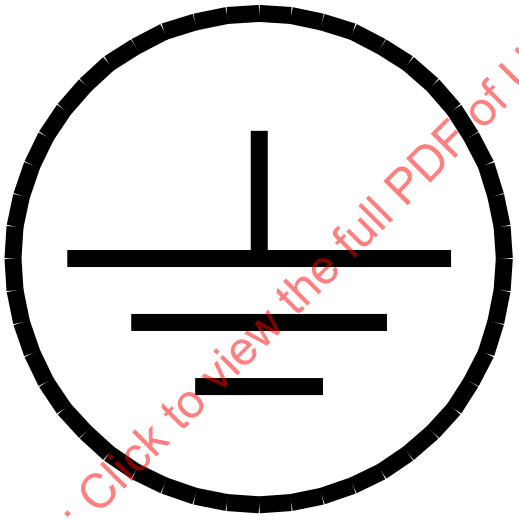
c) Footnote (c) does not apply.

In Mexico and the United States, Table 7 is not amended.

6.5.6 A terminal need not be provided with a controller that is marked to indicate the pressure wire connector or component terminal kits that are intended for use with the controller. A wire connector of the type mentioned shall be installed in the equipment at the factory with instructions, if required, for proper connection to the conductor. A terminal kit shall be described in the instructions by model number and manufacturer's name.

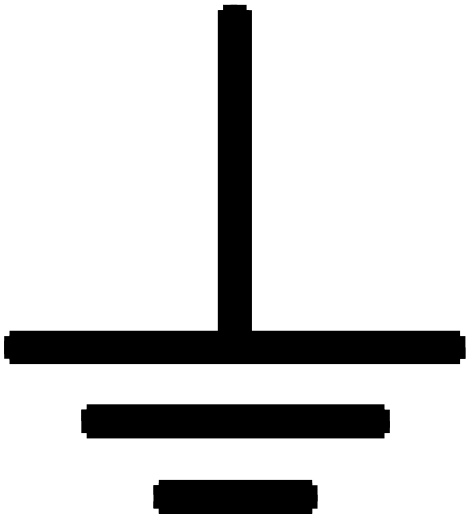
6.5.7 A wire-binding screw intended for the connection of a field-installed equipment grounding conductor shall have a green colored head that is hexagonal, slotted, Robertson, Phillips, Allen, Torx™, or any combination. See 6.4.6 – 6.4.10.

6.5.8 A terminal intended for connection of an equipment grounding or bonding conductor shall be plainly identified with the symbol



(IEC Publication 60417, Symbol 5019)

or



(IEC Publication 60417, Symbol 5017)

or with "G," "GR," "GRD," "Ground," "Grounding," or other equivalent marking.

6.6 Service equipment

6.6.1 In the United States, controllers for use with electric motor driven fire pumps and intended for use as service equipment shall comply with the requirements in Annex A, item 10. See 16.9 and 16.10 for markings.

In Canada and Mexico, this requirement does not apply.

6.6.2 In Canada, a separate service box is required.

6.7 Wire bending space

6.7.1 The distance between the end of a pressure wire connector or terminal block for connection of a field installed wire and the wall of the enclosure toward which the wire is directed shall be not less than that indicated in Table 4. The distance shall be measured in a straight line from the centre of the opening in the connector, in the direction in which the wire leaves the terminal, perpendicular to the enclosure wall.

6.7.2 In Canada, the wire bending space required by 6.7.1 shall be determined by Annex A, item 20.

In Mexico and the United States, this requirement does not apply.

6.7.3 The required bending space shall be based on the size of field wire to be connected to the connector or terminal in accordance with 6.4.

6.8 Internal wiring, busbars, and connections

6.8.1 Insulated conductors shall be suitable for the service intended with respect to voltage, temperature, and grouping. Conductors shall be copper and shall be not smaller than 0.2 mm^2 (24 AWG). The temperature rating shall be not less than 90°C (194°F) unless investigation proves the suitability of other conductors.

6.8.2 The requirements of 6.8.1 apply only to the wiring furnished on or in industrial control equipment as a part of the equipment. They do not apply to the supply wiring run to control equipment, to motors, or to other apparatus.

6.8.3 In Mexico and the United States, for motor and control-circuit applications, the use of Table 9 as a guide in selecting the conductor sizes in a controller may obviate the need to perform a temperature test on the wire. See temperature test in Annex A, item 9.

In Canada, for motor and control circuit applications, the use of Table 2 in Annex A, item 2, for selecting the conductor sizes, shall obviate the need to perform a temperature test on the wire.

6.8.4 Conductors that are in a circuit only during the motor starting period are not required to be sized for continuous duty but shall be sized according to their duty cycle.

6.8.5 Notwithstanding 6.8.1, conductors smaller than 0.2 mm^2 (24 AWG) shall be permitted for wiring of printed circuit boards and interconnecting wiring between electronic modules and subassemblies.

6.8.6 Conductors in an assembly intended for use in a complete enclosure shall be insulated for the highest voltage normally occurring between such conductors unless the wires are grouped so as to segregate the several voltages.

6.8.7 Wires shall be supported or secured or otherwise run in suitable raceways, in order that they will not come into contact with moving parts or rest on sharp edges or projections that might cause abrasion of the insulation. Wires shall be of flexible or extra-flexible construction where they make connection to electrical equipment mounted on a hinged door. If the flexing section of the wiring is liable to come in contact with grounded metal parts, that portion of the wiring shall be given additional protection with wrappings of tape or the equivalent or enclosed in nonmetallic flexible tubing or conduit.

6.8.8 Additional insulation is not required if the test described in 7.5 is completed without evidence of damage to the wiring.

6.8.9 Internal wiring shall not be in contact with bare live parts of opposite polarity or with bare live parts of other circuits.

6.8.10 A bare conductor, including pigtails and coil leads, shall be supported so that the spacings required elsewhere in this Standard will be maintained unless covered by suitable insulating sleeving or tubing.

6.8.11 All busbars and connections shall be readily accessible after installation of the controller.

6.8.12 All busbars and connections shall be arranged so that disconnection of the external circuit conductors will not be required.

6.8.13 Fuses shall be readily accessible.

6.8.14 Clamps and guides, either metallic or nonmetallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion or cold flow of the insulation does not occur. Auxiliary nonconducting mechanical protection shall be provided under a metallic clamp that exerts pressure on a conductor having thermoplastic insulation less than 0.8 mm (1/32 inch) thick and having no overall braid.

6.8.15 Insulated grounding and bonding conductors shall be identified by the color green with or without one or more yellow stripes. No other leads shall be so identified in the field wiring area.

6.8.16 All splices and connections shall be mechanically secure and shall provide electrical continuity.

6.8.17 Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint shall be mechanically secure before soldering.

6.8.18 A printed wiring board joint is not required to be mechanically secure before soldering.

6.8.19 A lead shall be considered to be mechanically secure when it is:

a) Wrapped at least halfway (180 degrees) around a terminal;

b) Provided with at least one right angle bend when passed through an eyelet or opening; or

c) Twisted with other conductors.

6.8.20 If stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire cannot contact other uninsulated live parts not always of the same polarity as the

wire, and de-energized metal parts. This may be accomplished by any acceptable means, including use of machine- or tool-applied pressure terminal connectors, soldering lugs, or crimped eyelets, or soldering all strands of the wire together.

6.8.21 In Mexico and the United States, a splice shall be provided with insulation equivalent to that of the wires involved.

In Canada, splices are not allowed.

6.8.22 In determining if splice insulation consisting of coated-fabric, thermoplastic, or other types of tubing is acceptable, consideration shall be given to electrical and mechanical properties, including dielectric voltage-withstand ability, heat resistance, and moisture resistance. Thermoplastic tape shall not be wrapped over a sharp edge or connection.

6.9 Provisions for use of test instruments

6.9.1 Means shall be provided on the exterior of the controller to read all line currents and all phase-to-phase voltages within ±5 percent of full scale.

6.10 Control circuit

6.10.1 Circuits that are necessary for proper operation of the controller shall not have overcurrent protective devices connected in them.

6.10.2 The secondary of a control transformer shall be ungrounded except as required in 10.5.1.[3)]

[3)] 6.10.2 originated from 10.3.5.2 of the 2010 edition of NFPA 20. Reprinted with permission from NFPA 20-2010, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2009, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.11 Auxiliary circuits

6.11.1 An auxiliary circuit shall be provided with overcurrent protection in accordance with Annex A, item 2. Failure of auxiliary circuits shall not prevent the controller from starting the fire pump.

6.12 Manual controls

6.12.1 All switching equipment for manual use in isolating, connecting or disconnecting, or starting or stopping the motor shall be externally operable.

6.13 Surge arresters

6.13.1 A surge arrester complying with Annex A, item 14, or Annex A, item 15, shall be installed from each line to ground. These devices shall be rated to suppress voltage surges above the rated line voltage of the controller.

6.13.2 Notwithstanding 6.13.1, a controller rated in excess of 600 V is not required to be provided with a voltage surge arrester.

6.13.3 Notwithstanding 6.13.1, a voltage surge arrester is not required to be provided when the controller is capable of withstanding a 10 kV impulse in accordance with Annex A, item 16, without damage.

6.14 Isolating switch

6.14.1 The isolating switch shall have an ampere rating at least 115 percent of the motor rated full-load current as determined from Table 2 and Table 3; and shall be a manually operable switch that complies with Annex A, item 4, or a molded case switch that complies with Annex A, item 8. See 16.5 for marking.

6.14.2 A molded case isolating switch provided with self-protecting instantaneous short circuit overcurrent protection complies with 6.14.1 when the switch is such that it does not trip unless the circuit breaker in the same controller trips.

6.14.3 An isolating switch shall be externally operable.

6.14.4 A horsepower or kW rated motor circuit switch complying with Annex A, item 4, may also be used as the isolating switch.

6.14.5 In Mexico and the United States, a non-load break rated isolating switch operating handle shall be provided with a spring latch that shall be so arranged that it requires the simultaneous releasing of the latch in order to open or close the switch and that shall be marked as per 16.5.

In Canada, an isolating switch shall be interlocked with the circuit breaker and shall be marked as per 16.5.

6.14.6 For a construction with the isolating switch and the circuit breaker so interlocked that the isolating switch is not capable of being opened or closed while the circuit breaker is closed, the latch and markings in 6.14.5 are not required.

6.14.7 When a load break rated isolating switch or a switch complying with 6.14.4 is used, the latch and markings in 6.14.5 are not required.

6.15 Circuit breaker – disconnecting means

6.15.1 The motor branch circuit shall be protected by a circuit breaker that complies with Annex A, item 8, connected directly to the load side of the isolating switch with one pole connected to each ungrounded circuit conductor.

6.15.2 A circuit breaker shall have the following mechanical characteristics:

a) Be externally operable and resettable (see 6.16.1(c));

b) Be trip free of the handle; and

c) Be marked in accordance with 16.7.

6.15.3 The electrical characteristics of the circuit breaker disconnecting means shall:

a) Have a continuous current rating not less than 115 percent of the rated full-load current of the motor;

b) Have non-thermal type overcurrent sensing elements, if provided;

c) Be of the instantaneous-only circuit breaker type with an instantaneous trip setting of not more than 20 times the full-load current to allow normal starting or emergency run mechanical starting of the motor without tripping; and

d) Be adequate to provide the short circuit rating of the controller, as determined by testing per 7.1.

6.15.4 A circuit breaker shall not trip when:

a) Starting a motor from rest in the across-the-line (direct-on-line) mode, whether or not the controller is of the reduced inrush starting type; and

b) Power is interrupted from a running pump motor, or if the pump motor is restarted in less than 3 seconds after being shut down. If a control circuit preventing a motor re-start within 3 seconds is provided, this requirement shall not apply.[4)]

[4)] 6.15.4 originated from 10.4.3.3.1.1 and 10.4.3.3.1.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.16 Locked rotor overcurrent protection

6.16.1 Locked rotor overcurrent protection sensing shall be located within the fire pump controller between the load side of the isolating switch and the controller output terminals and have the following characteristics:

a) Be of the non-thermal time delay type having a tripping time between 8 and 20 seconds at locked rotor current. (Unless otherwise specified, this is 600 percent of rated full-load current.);

b) Have a tripping characteristic such that tripping shall not occur within 3 min at a minimum of 300 percent of rated full-load current;[5)]

c) Be provided with visual means or markings that clearly indicate that proper settings have been made;

d) Be resettable for operation immediately after tripping, with the tripping characteristics unchanged;

e) Tripping shall be accomplished by opening the circuit breaker (disconnecting means). (See 6.15);

f) Calibration (trip and hold currents) shall apply to all poles of the locked rotor protection.

[5)] Item (b) of 6.16.1 originated from item (1)(b) of 10.4.4 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.16.2 The locked rotor overcurrent protection shall be subjected to the test described in 7.8.

6.17 Motor starting means

6.17.1 Full voltage starting

6.17.1.1 A motor contactor that complies with Annex A, item 18, shall be of the magnetic type with a contact in each ungrounded conductor.

6.17.1.2 For controllers rated 600 V or less, the operating coil for the main contactor shall be supplied directly by the primary supply circuit.

6.17.2 Reduced voltage starting

6.17.2.1 A reduced voltage controller shall comply with Annex A, item 18.

6.17.2.2 For electrical operation of reduced voltage controllers, timed automatic acceleration of the motor shall be provided. The period of motor acceleration shall not exceed 10 seconds. After 10 seconds the fire pump controller shall apply full line voltage to the motor.

6.17.2.3 For controllers rated 600 V or less, the operating coil for the contactor(s) shall be supplied directly by the primary supply circuit.

6.17.2.4 Starting resistors shall be designed to permit one 5 second starting operation in each 80 seconds for a period of not less than 1 hour. This requirement shall not apply to the transition resistors in a wye-delta closed transition controller.

6.17.2.5 A starting reactor or autotransformer shall permit one 15 second starting operation every 240 seconds for a period of not less than 1 hour. Alternately, a controller over 132 kW (200 hp) shall allow three 30 second starts separated by 30 second rest intervals in each hour for 2 hours.

6.17.2.6 Soft start units shall be horsepower rated or specifically designed for the service.

6.17.2.7 The bypass contactor shall comply with 6.17.1.1.

6.17.2.8 Soft start units shall comply with the duty cycle requirements in accordance with 6.17.2.5.

6.17.2.9 A fire pump controller employing a reduced voltage starting means shall also comply with 6.21.3 for emergency run control.

6.17.2.10 For wye-delta or part winding start motors, the starting contactor shall be rated as follows:

a) Part winding: each contactor carries no less than 50% of the motor FLA;

b) Wye-delta: line contactors carry no less than 58% of the motor FLA. Wye contactor carries 33 percent;

c) For primary resistor, auto-transformer, primary reactor and soft start carry no less than 65% of motor FLA. Auto-transformer neutral contactor carries no less than 25% of motor FLA; and

d) Closed transition wye-delta transition contactor current is at least equal to 58% of the rated line voltage divided by the transition resistor resistance.

6.17.2.11 A fire pump controller employing a wye-delta reduced voltage starting means shall be electrical and mechanically interlocked.

6.17.3 Ratings

6.17.3.1 Running contactors shall be sized for both the locked rotor currents and the continuous running currents encountered.[6)]

[6)] 6.17.3.1 originated from 10.4.5.1.1 of the 2010 edition of NFPA 20. Reprinted with permission from NFPA 20-2010, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2009, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.17.3.2 Starting contactors shall be sized for both the locked rotor currents and the acceleration (starting) currents encountered.[7)]

[7)] 6.17.3.2 originated from 10.4.5.1.2 of the 2010 edition of NFPA 20. Reprinted with permission from NFPA 20-2010, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2009, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.18 Use of sensing devices

6.18.1 No undervoltage, phase loss, frequency sensitive, ground-fault, or other sensor (s) shall be installed that automatically or manually prohibit(s) electrical actuation of the motor contactor.

6.18.2 Sensors shall be permitted to prevent a three phase motor from starting under single-phase conditions. These shall not cause disconnection of the motor when running at the time of a single-phase occurrence. Such sensors shall be monitored to provide a local visible alarm in the event of malfunction of the sensors. When single-phase (loss of phase) motor protection is provided:

a) The failure of any circuit or component whose primary function is the detection, signaling, or response to a loss of phase of the power source shall not prevent the motor from electrically starting under restored power conditions.

b) If the single-phase loss condition occurs while the motor is running, any circuit or component whose primary function is the detection, signaling, or response to a loss of phase of the power source shall not interrupt the power to the motor, including low rpm and locked rotor conditions.

c) The voltage threshold (drop out) for any circuit or component whose primary function is protection of the motor from a loss of phase of the power source shall not exceed 70 percent of the nominal line voltage.

d) When the motor is protected from a loss of phase of the power source, electrical starting capability shall be automatically restored within 10 seconds upon the restoration of power.

6.19 Provision for alarm and signal devices

6.19.1 A visible indicator shall monitor the availability of power in all phases at the line terminals of the motor starting means. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

6.19.2 When power is supplied from an integral transfer switch, monitoring of the availability of power from each power source shall be permitted at any point electrically upstream of the line terminals of the contactor, provided all sources are monitored.

6.19.3 A visible indicator shall monitor for phase reversal at the line terminals of the motor starting means. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

6.19.4 When power is supplied from an integral transfer switch, monitoring for phase reversal from each power source shall be permitted at any point electrically upstream of the line terminals of the contactor, provided all sources are monitored.

6.19.5 Controllers shall be provided with contacts (open, closed, or both) to operate alarm circuits that indicate the following conditions:

a) Controller in a motor running condition;

b) Loss of phase on the line side of the motor contactor, in any phase, falls below 85 percent of nominal controller voltage;

c) Phase reversal on the line side of the motor contactor on a polyphase controller; and

d) Controller connected to alternate source – contacts (open, closed or both), mechanically actuated by the transfer switch mechanism, shall be provided to indicate whenever the alternate source is the source supplying power to the controller. See 11.5.4(d).

6.19.6 The alarm contacts specified in 6.19.5 shall be rated at 125 V minimum and have provision for connection to an external circuit.

6.19.7 Controllers shall detect the loss of any phase regardless of whether the motor is running or not. See 7.6.

6.19.8 A visible and audible alarm shall be provided when the controller fails to start from the automatic mode.

6.20 Automatic controllers

6.20.1 General

6.20.1.1 An automatic controller shall comply with the requirements for a non-automatic controller specified in 6.21.

6.20.1.2 The controller shall be in a fully functional state within 10 seconds upon application of AC power.

6.20.1.3 An automatic controller shall not have a manually actuated selector switch for selecting between automatic and non-automatic modes of operation, nor shall the switch have an “OFF” position, such as Auto-Off-Manual or Hand-Off-Auto.

6.20.2 Water pressure control

6.20.2.1 An automatic water pressure controller shall be provided with a pressure-activated device having high and low calibrated set points in the controller circuit. No pressure snubber or restrictive orifice shall be employed within the pressure switch. The device shall be responsive to water pressure in the fire protection system as specified in 6.20.2.4.

6.20.2.2 There shall be no valve or other restrictions within the controller ahead of the pressure switch or pressure responsive means.[8)]

[8)] 6.20.2.2 originated from 40.30.3 of the 2010 edition of NFPA 20. Reprinted with permission from NFPA 20-2010, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2009, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.20.2.3 Each controller pressure sensing control circuit shall operate independently.[9)]

[9)] 6.20.2.3 originated from 10.10.7.4.1 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.20.2.4 When an automatic controller is provided with a pressure recording device to sense and record the pressure in each fire pump controller pressure sensing line at the input to the controller, the recorder shall be capable of operating for at least 7 days without being reset or rewound.

6.20.2.5 The pressure recording device of 6.20.2.4 shall be mounted external to the controller, or in a barriered compartment, or behind a door in a barriered enclosure, or other provisions shall be made to reduce the risk of contact with uninsulated live parts during normal servicing of the pressure recording device.

6.20.2.6 The pressure sensing element of a pressure-activated and pressure recording device shall be capable of withstanding a momentary surge of pressure of 2,758 kPa (400 psi) or 133 percent of the fire pump controller rated operating pressure, whichever is higher, without losing its accuracy.

6.20.2.7 A controller that starts the motor before the pressure-activated device specified in 6.20.2.4 under specified conditions shall use a drop-out relay to start the motor.

6.20.2.8 When the controller has a means for connection of a circuit for the remote manual starting of the fire pump, this means shall be such that the fire pump motor is not capable of being stopped from the remote station.

6.20.2.9 For sequence starting of multiple pumps, the controller for each unit of multiple pump units shall incorporate a sequential timing device to prevent any one driver from starting simultaneously with any other driver. If water requirements call for more than one pumping unit to operate, the units shall start at intervals of 5 to 10 seconds. Failure of a leading driver to start shall not prevent subsequent drivers from starting.

6.20.2.10 Controller actuation by the pressure switch at the low adjustment setting shall initiate the pump starting sequence, unless the pump is already in operation.

6.20.2.11 A pressure sensing switch or transducer with internal or external amplifier shall comply with 7.7.

6.20.2.12 A pressure transducer shall be permanently marked on the exterior to include the name or trademark of the manufacturer, serial and identification number, pressure range, electrical rating and date of manufacture.

6.20.2.13 Instructions shall be provided for setting the start and stop pressures for the fire pump.

6.20.2.14 Metallic pressure sensing lines and fittings shall be brass, copper, or series 300 stainless steel pipe or tube. The fitting for connection to the external pressure sensing line shall be of 15 mm (½ in. nominal).

6.20.2.15 The solenoid drain valve shall be a fully ported 15 mm (1/2 in.) diameter nominal pipe size and have internal passages of 3 mm (1/8 in.) diameter or larger.

6.20.3 External circuits connected to controllers

6.20.3.1 External control circuits that extend outside the fire pump room shall be arranged so that failure of any external circuit (open, ground fault or short circuit) shall not prevent operation of pump(s) from all other internal or external means. Breakage, disconnecting, shorting of the wires, ground fault or loss of power to these circuits may cause continuous running of the fire pump but shall not prevent the controller(s) from starting the fire pump(s) due to causes other than these external circuits.

6.20.3.2 No undervoltage, phase loss, frequency sensitive, or other sensor (s) shall be installed that automatically or manually prohibit(s) electrical actuation of the engine starting contactor.

6.20.4 Non-pressure switch actuated automatic controller

6.20.4.1 A non-pressure switch actuated automatic controller shall be activated by a remote sensor, such as a smoke detector, fire alarm, carbon monoxide detector, or other such device. A pressure switch shall not be required.

6.20.4.2 The starting sequence of the controller shall be initiated by the opening of the remote contact(s) of the device specified in 6.20.4.1.

6.20.4.3 No other means of stopping the fire pump motor shall be provided except for those on the controller.

6.20.5 Fire protection equipment control

6.20.5.1 Controllers with provision to supply special water control equipment (deluge valves, dry pipe valves, etc.) may start the driver before the pressure-activated switch(es) would do so. The controller shall be equipped with an opening of contacts to start the engine upon operation of the fire protection equipment.

6.20.5.2 The starting sequence of the controller shall be initiated by the opening of the control circuit loop containing the remote equipment.

6.20.6 Weekly program timer

6.20.6.1 The controller equipment shall be arranged to automatically start and run the motor for at least 10 min once a week. A solenoid valve drain on the pressure control line shall be the initiating means.

6.20.6.2 A means to disable the timer shall be provided to permit the weekly test to be initiated manually.

6.20.6.3 The solenoid valve drain is not required to be the initiating means for non-pressure-activated controller.

6.20.6.4 An automatic pressure-activated call to start signal, or a call to start signal from a manual start device or a remote start device, shall override the weekly program timer.

6.21 Non-automatic controllers

6.21.1 General

6.21.1.1 A non-automatic controller shall be manually actuated by separate electrical and mechanical means.

6.21.1.2 The controller shall be in a fully functional state within 10 seconds upon application of AC power.

6.21.2 Manual electric control at controller

6.21.2.1 A manually operated switch shall be provided on the controller so that when the fire pump motor is started manually, its operation is not affected by the pressure-activated switch, if provided. The fire pump motor shall remain in operation until manually stopped.

6.21.3 Emergency run mechanical control at controller

6.21.3.1 A controller shall be equipped with an emergency run handle or lever that operates to close the magnetic motor controller mechanism mechanically. This handle or lever shall provide for non-automatic continuous running operation of the motor (s) independent of any electric control circuits, magnets, or equivalent devices, and independent of the pressure-activated control switch. Means shall be incorporated for mechanically latching or holding of the handle or lever for manual operation in the actuated position. The mechanical latching may be automatic or manual.

6.21.3.2 The handle or lever shall be arranged to move in one direction only from "OFF" to final position.

6.21.3.3 The magnetic motor controller shall return automatically to the "OFF" position if the operator releases the handle or lever in any but the full running position.

6.21.3.4 The operating handle of the emergency run mechanical control shall be marked in accordance with 16.21.[10)]

[10)] 6.21.3.4 originated from 10.5.3.2.4 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

6.22 Stopping methods

6.22.1 Stopping the fire pump motor by the controller shall be accomplished by manual operation of a stop pushbutton on the outside of the controller enclosure. In the case of an automatic controller, pressing and releasing the pushbutton shall return the controller to the automatic position.

6.22.2 If a controller is arranged for automatic stopping after starting causes have returned to normal, a timer set for at least 10 min operating time after initial motor activation shall be provided.

6.22.3 Means shall be provided to disable automatic stopping. A visible indicator shall be provided to indicate that automatic stopping is disabled or enabled.

6.23 Power interruption

6.23.1 In case of a power interruption the fire pump controller operating parameters shall be retained.

6.24 Ground fault and arc fault protection

6.24.1 No ground fault or arc fault interruption means shall be installed in any fire pump control or power circuit.[11)]

[11)] 6.24.1 originated from 9.1.8.1 and 9.1.8.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

PERFORMANCE

7 Performance Tests

7.1 Short circuit test – general

7.1.1 The controller or combination controller/transfer switch shall be type tested to verify the short circuit rating. The test shall be done for both standard-fault currents and high-fault currents as referenced in Annex A, item 9.

7.1.2 Annex D, Test Samples (Informative), contains information about testing components and test samples.

7.1.3 After completing the test specified in 7.2 and 7.3, and after the circuit breaker has cleared the fault, a controller shall comply with the following:

a) In Mexico and the United States, there shall be no discharge of parts. The contactor contacts may weld or completely disintegrate.

In Canada, there shall be no discharge of parts. Complete disintegration shall not be permitted. Complete disintegration of the contact shall be considered to have occurred when the contacts are not capable of carrying rated current or if temperatures cannot be stabilized at rated current.

b) There shall be no damage to a conductor or terminal connector, and no conductor shall pull out of a terminal connector.

c) There shall be no breakage of insulating bases to the extent that the integrity of the mounting of live parts is impaired.

d) The door or cover shall not be blown open, and it shall be possible to open the door or cover. Deformation of the enclosure shall not result in the accessibility of live parts as determined by the use of the finger probe specified in Annex A, item 9.

e) The circuit breaker and isolating switch, when provided, of the controller shall be capable of being opened manually with its operating handle.

f) In Mexico and the United States, the solid wire connected between the live pole and the enclosure shall not open.
In Canada, the solid wire connected between the live pole and the enclosure shall not open. The 30 A ground fuse shall not open for standard fault testing.

g) Neither end of the circuit breaker or isolation switch, when provided, shall be completely separated from the mounting means and the line terminals of the circuit breaker or isolating switch shall not bridge from the mounting means to dead-metal.

7.1.4 The controller shall be mounted as intended in service and tested with 1.2 m (4 ft) of wire attached to each load and line terminal. The wire shall be the smallest size having an ampacity of at least 125 percent of the maximum full-load motor-current rating of the current element. The wire size shall be in accordance with Table 5 based upon the wire temperature rating marked on the equipment. When the terminal will not receive that size of wire, or the equipment is marked to limit the size of wires, the maximum wire size shall be used. The load terminal leads shall be connected together.

Note: The line test wires may exceed 1.2 m (4 ft) in length if they are included in the circuit during calibration.

7.1.5 In Mexico and the United States, the enclosure of the controller shall be connected through a solid conductor without a fuse to the live pole that is judged to be least likely to strike the ground on the load side of the limiting impedance by a 5.3 mm^2 (10 AWG) copper wire 1.2 – 1.8 m (4 – 6 ft) long.

In Canada, the enclosure of the controller shall be connected through a solid conductor without a fuse to the live pole that is judged to be least likely to strike the ground on the load side of the limiting impedance by a 5.3 mm^2 (10 AWG) copper wire 1.2 – 1.8 m (4 – 6 ft) long. A 30 A fuse shall be connected in the solid conductor for standard fault testing.

7.1.6 The connection described in 7.1.5 shall be made with 3.3 or 2.1 mm^2 (12 or 14 AWG) copper wire if the branch-circuit conductors the equipment is intended to be connected to are 3.3 or 2.1 mm^2 (12 or 14 AWG), respectively.

7.1.7 Standard fault test circuits shall be calibrated to the values specified in Table 6 in accordance with the requirements for calibration of test circuits for the short circuit test in Annex A, item 22.

7.1.8 High fault test circuits shall be calibrated to a value specified in Table 10 in accordance with the requirements for calibration of test circuits for the short circuit test in Annex A, item 22.

7.1.9 Three phase tests shall be considered to cover single-phase tests for a device of the same design.

7.1.10 The enclosure cover shall be held closed only by the intended latch mechanism and securement means.

7.1.11 Following the short circuit testing, a controller shall be subjected to 7.4.

7.2 Short circuit test – standard fault currents

7.2.1 The isolating switch, if provided, and the circuit breaker shall be in the fully closed position. The magnetic motor contactor shall be held closed by a separate electrical supply. The test circuit shall be closed on the test sample as described in 7.3. See 7.3.1 for test set-up. Two operations (“O” shots), are required. Motor contactor contacts or the complete contactor may be replaced after the first test (“O” shot).

7.3 Short circuit test – high fault currents

7.3.1 Two successive operations shall be conducted by closing the test circuit on the equipment (“O” shot), using random closing and closing the equipment on the circuit (“CO” operation). Motor contactor contacts or the complete contactor may be replaced after the first test (“O” shot).

7.3.2 “O” shot: The circuit breaker, isolating switch, and the contactor shall be in the fully closed position when closing the test circuit on the equipment.

7.3.3 The motor contactor shall be held in the closed position either mechanically or by a separate electrical circuit.

7.3.4 “CO” shot: The circuit breaker and isolating switch shall be in the fully closed position. The contactor shall be closed onto the test circuit by a separate electrical signal.

7.4 Dielectric voltage-withstand test

7.4.1 Following the short circuit tests, a controller shall withstand, without breakdown, a test potential of twice rated voltage, but not less than 900 V, applied for not less than 1 min as follows:

a) Between line and load terminals of the circuit breaker in the open position;

b) Between line and load terminals of the isolating switch, when provided, with the switch in an open position;

c) Between terminals of opposite polarity with the circuit breaker and isolating switch, when provided, in an open position; and

d) Between live parts and the overall enclosure with the circuit breaker and isolating switch, when provided, both opened and closed.

7.5 Wire flexing test

7.5.1 The wiring to components mounted on a door shall be tested by opening the door as far as possible – restraints such as a chain shall remain in place – and then closing it for 500 cycles of operation. Following this test, the equipment shall be subjected to the dielectric voltage withstand test described in 7.4.1 (shall be twice rated V + 1000 V +20% for 1 s) applied between conductors, and between conductors and ground with the door in the fully opened position.

7.6 Phase loss detection test

7.6.1 As a result of the tests specified in 7.6.2 and 7.6.3, the visual indicators in 6.19.1 shall indicate the loss of phase, and the contacts in 6.19.5 shall change state.

7.6.2 Each power wiring lead, and neutral conductor, on the input (line) side of the controller shall be disconnected from its source of supply while other leads remain intact. The test shall be performed with a minimum 4 kW (5 hp) rated motor.

7.6.3 The test specified in 7.6.2 shall be performed under the following conditions:

a) While the motor is running unloaded at rated voltage; and

b) With the motor at rest.

7.7 Pressure switch/transducer tests

7.7.1 General

7.7.1.1 A pressure switch/transducer shall comply with the tests shown in 7.7.2 – 7.7.9.2. All tests shall be conducted on the same sample. The order of testing shall be as shown below.

7.7.2 Output accuracy

7.7.2.1 At standard room ambient temperature [10 – 40° C (50 – 104° F)] and at the minimum input voltage marked on the device, the pressure switch (transducer) output reading (signal) shall be within ±5% of full scale, but not more than ±103 kPa (±15 psi). A minimum of 10 equidistance readings shall be taken over the full range of the device.

7.7.3 Repeatability

7.7.3.1 At standard room ambient temperature [10 – 40° C (50 – 104° F)] and using the minimum input voltage marked on the device, when pressure is varied from zero to full scale, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1. For the next two sets of curves, using the mid-point of the input voltage marked

on the device, when pressure is varied from zero to full scale, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1. For the last two sets of curves, using the maximum input voltage marked on the device, when pressure is varied from zero to full scale, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi) of the curve obtained for output accuracy as per 7.7.2.1. A minimum of 10 equidistance readings shall be taken over the full range of the device for each of the five curves.

7.7.4 Supply voltage coefficient

7.7.4.1 The pressure switch/transducer accuracy shall be with ± 1% of full scale, but not more than ±21 kPa (±3 psi) when the controller input voltage is varied from 85% of controller rated voltage to 110% of controller rated voltage. This coefficient shall be checked at no less than 10 equidistant pressures including zero and full scale. If the calculated input voltages are within the minimum and maximum input voltages performed in the repeatability test per 7.7.3.1, then this test is not required.

7.7.5 Pressure capability

7.7.5.1 Overpressure withstandability: After sustaining 133% maximum rated working pressure for at least 5 min, the pressure switch/transducer shall be tested at standard room ambient temperature [10 – 40°C (50 – 104°F)] and using the minimum input voltage marked on the device; when pressure is varied from zero to full scale, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1.

7.7.6 Temperature coefficient (temperature drift)

7.7.6.1 At an ambient temperature of 2°C (36°F) after a 12 hour conditioning period, the pressure switch (transducer) using the minimum input voltage marked on the device, when pressure is varied from zero to full scale and back, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1. To facilitate testing of the temperature-conditioned device, the device may be removed from the conditioning temperature chamber. All readings shall be completed within 3 min after test device withdrawal from conditioning temperature chamber. A minimum of 10 equidistance readings shall be taken over the full range of the device.

7.7.6.2 At an ambient temperature of 60°C (140°F) after a 12 hour conditioning period, the pressure switch (transducer)using the minimum input voltage marked on the device, when pressure is varied from zero to full scale and back, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1. To facilitate testing of the temperature-conditioned device, the device may be removed from the conditioning temperature chamber. All readings shall be completed within 3 min after test device withdrawal from conditioning temperature chamber. A minimum of 10 equidistance readings shall be taken over the full range of the device.

7.7.7 Endurance

7.7.7.1 The device shall be subjected to 6,000 pressure fluctuation cycles. Each cycle shall be from zero pressure to no less than rated full-scale pressure. The output shall be connected to an electrical load equal to the maximum rating of the device. There shall be no failures, and for the device at standard room ambient temperature [10 – 40°C (50 – 104°F)] and using the minimum input voltage marked on the device, when pressure is varied from zero to full scale, the output pressure curve shall retrace, within ±1% of full scale, but not more than ±21 kPa (±3 psi), the curve obtained for output accuracy as per 7.7.2.1.

7.7.8 Dielectric strength (voltage withstand)

7.7.8.1 The pressure switch/transducer shall meet the test criteria in 7.7.8.2 and 7.7.8.3.

7.7.8.2 Where the transducer operating (power supply) voltage is 50 volts or less, a test voltage of 500 V AC shall be applied between the electrical terminals and the exterior surface and the pressure fitting for a period of 1 min. There shall be no evidence of arcing or breakdown.

7.7.8.3 Where the transducer operating (power supply) voltage exceeds 50 volts, a test voltage of 1000 V AC + 2 times the operating voltage shall be applied between the electrical terminals and the exterior surface and the pressure fitting for a period of 1 min. There shall be no evidence of arcing or breakdown.

7.7.9 Burst pressure

7.7.9.1 Transducers shall be able to sustain 2 times the maximum rated working pressure, or at least 13,790 kPa (2,000 psi), for at least 5 min. The device shall not rupture, nor shall it leak.

7.7.9.2 Bourdon tube pressure switches shall be able to sustain 2 times the maximum rated working pressure.

7.8 Locked rotor overcurrent protection test

7.8.1 When tested in accordance with 7.8.2 – 7.8.12, the locked rotor overcurrent protection feature of a fire pump controller shall:

a) Not trip within 3 min at 300 percent of motor full-load current;

b) Trip the circuit breaker between 8 and 20 seconds at motor locked rotor current (600 percent of motor-full load current).

c) Be able to be manually reset immediately after tripping, with the tripping characteristics unchanged. See 7.8.12.

7.8.2 The fire pump controller/locked rotor overcurrent protection shall be mounted as intended.

7.8.3 Wiring connections shall be made as described in 7.10.11.

7.8.4 Any convenient voltage source may be used to provide the specified test current.

7.8.5 The fire pump controller/locked rotor overcurrent protection shall be tested at ambient temperatures of 25°C (77°F) and 50°C (122°F).

7.8.6 A test current equal to the rated motor locked rotor current (or 600 percent of the rated motor full-load current) shall be generated by using any convenient test voltage and shall be sent through the fire pump controller or otherwise detected by the locked rotor overcurrent protector. The time from initial current generation to the time the locked rotor overcurrent protector trips to open the circuit shall be recorded.

7.8.7 Immediately after the test in 7.8.6, the locked rotor overcurrent protective device (circuit breaker) shall be manually reset and the test in 7.8.8 conducted.

7.8.8 A test current equal to the 300 percent of the rated motor full-load current shall be generated by using any convenient test voltage and shall be sent through the fire pump controller or otherwise detected by the locked rotor overcurrent protector. The time from initial current generation to the time the locked rotor overcurrent protector trips to open the circuit shall be recorded.

7.8.9 Immediately after the test in 7.8.8, the locked rotor overcurrent protective device (circuit breaker) shall be manually reset and the process in 7.8.6 – 7.8.8 shall be repeated 3 more times (4 times total).

7.8.10 As an alternative to alternating the tests at 300 percent and at locked rotor current, all four trials may be conducted at one value (for example at 300 percent) before continuing with the tests at the remaining value, provided the same sample is used.

7.8.11 The same sample shall be used for all 8 trials (4 trials at 300 percent, 4 trials at locked rotor).

7.8.12 The results of the above test shall be considered to be in compliance, if, in addition to the definite-time constraints in 7.8.1(a) and 7.8.1(b), there is no more than a 10 percent variance between any one data point and the mean average for that set of data.

7.9 Barrier dielectric strength test

7.9.1 A polymeric material used as a barrier at a thickness less than specified in Clause 6.3 shall comply with the test described in 7.9.2 and 7.9.3.

7.9.2 A sample of the polymeric material, at its used thickness, shall withstand for 1 min a dielectric voltage of 5000 V rms, 50 – 60 Hz, both after conditioning for both:

a) 40 h at 23.0 ±2°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, and

b) 96 h at 35.0 ±2°C (95.0 ±3.6°F) and 90 ±5 percent relative humidity.

In Mexico, the dielectric voltage is defined as 5,000 V rms, 60 Hz.

7.9.3 Subjected to a 60 second Dielectric Voltage Withstand Test using the AC RMS test voltage values of Table 12 or Table 13 as applicable, corresponding to the required through-air spacing.

7.10 Temperature test

7.10.1 As tested under the conditions described in 7.10.2 – 7.10.30, fire pump controllers and associated equipment shall:

a) Not attain a temperature at any point so high as to constitute a risk of fire or fire hazard or adversely affect any materials employed in the equipment;

b) Not exceed the temperature limit for any individual component within the equipment; and

c) Not exceed the temperature rise above the test ambient at specific points greater than those specified in Table 15 and Table 17.

7.10.2 To determine whether a fire pump controller complies with the temperature test requirements, it shall be tested as in 7.10.3 – 7.10.37.

7.10.3 Fire pump controllers shall be operated under normal conditions as described in the manufacturer's installation instructions.

7.10.4 Equipment shall carry its rated current continuously.

7.10.5 The test current for a horsepower rated device shall be as specified in Table 2 and Table 3.

7.10.6 An auxiliary device for controlling a contactor, a relay or another magnetically operated device shall carry a test current that corresponds to the maximum break current consistent with the switch rating.

7.10.7 The test conditions shall be established so that each current carrying component carries the maximum rated current of the controller. Three phase controllers shall be tested on a three phase current source.

7.10.8 A low voltage source of supply may be used for temperature tests on parts other than voltage rated coils.

7.10.9 The temperature test shall be conducted with the fire pump controller mounted as intended in use.

7.10.10 The fire pump controller, or associated equipment, shall be tested in the enclosure provided by the manufacturer.

7.10.11 External field connections to the fire pump controller shall be made by one of the methods described in 7.10.12 – 7.10.16.

7.10.12 Fire pump controllers shall be tested with 1.2 m (4 ft) of copper wire attached to each field-wiring terminal.

7.10.13 The wire shall be of the smallest size having an ampacity of at least 125 percent of the maximum full-load motor-current in accordance with 7.10.5.

7.10.14 The wire size shall in accordance with Table 5 based on the wire temperature rating marked on the equipment.

7.10.15 If the equipment is marked to limit the size of the wire, the maximum allowable wire size shall be used.

7.10.16 When there is only provision for the connection of bus bars to equipment rated at 450 A or more, 6.4 mm (1/4 inch) thick copper bus bars of the width specified in Table 18 and at least 1.2 m (4 ft) in length shall be used.

7.10.17 The temperature test shall be conducted with plated bus bars. Black-painted bus bars shall not be used.

7.10.18 The spacing between multiple bus bars shall be 6.4 mm (1/4 inch) with no intentional wider spacing except as necessary at the individual terminals of the equipment.

7.10.19 The temperature test shall be conducted with the equipment placed in one of the following locations. The ambient temperature for the temperature test shall be based on one of the following:

a) Equipment shall be placed in the rated ambient temperature;

b) Equipment shall be placed in a non-air circulating test chamber with the ambient temperature of the test chamber adjusted to the rated ambient; or

c) Equipment may be tested in a lower ambient temperature provided the test results are adjusted linearly to the rated ambient temperature.

7.10.20 If reference measurements of ambient temperatures are necessary, several thermometers shall be placed at different points around the equipment at a distance of 900 – 1800 mm (35 – 70 inch). The thermometers shall be located in the path of the cooling medium, but shall be protected from drafts and abnormal heat radiation. The ambient temperature shall be the mean of the readings of the temperatures taken at equal intervals of time during the final quarter of the duration of the test.

7.10.21 The tests on all parts shall be made simultaneously, as the heating of one part can affect the heating of another part.

7.10.22 The temperature test shall be conducted until temperatures are constant.

7.10.23 A temperature rise shall be considered to be constant when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of the test (but not less than 10 min intervals), are constant within 1°C (1.8°F).

7.10.24 Temperatures shall be measured by thermocouple method or by resistance method, as described in 7.10.25 to 7.10.30.

7.10.25 The thermocouple method shall consist of the determination of temperature by the application of thermocouples to the hottest accessible parts with measurement by a suitable calibrated instrument.

7.10.26 The thermocouples shall be made of wires not larger than 0.21 mm^2 (24 AWG). The thermocouples and related instruments shall be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire shall conform with the requirements for special tolerance thermocouples specified in Annex A, item 23.

7.10.27 A thermocouple junction and adjacent thermocouple lead wire shall be securely held in good thermal contact with the surface of the material on which the temperature is being measured. In most cases, adequate thermal contact will result from securely taping or cementing the thermocouple in place, but if a metal surface is involved, brazing or soldering the thermocouple to the metal might be necessary.

7.10.28 The preferred method of measuring the temperature of a coil shall be the resistance method, but temperature measurements by either the thermocouple or resistance method are acceptable. The thermocouple method shall not be employed for a temperature measurement at any point at which supplementary insulation is employed.

7.10.29 The resistance method for temperature measurement as specified in Table 15 and Table 17 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta T = \frac{r_2}{r_1}(k + t_1) - (k + t_2)$$

where:

Δt is the temperature rise of the winding in degrees C;

r_2 is the resistance of the coil at the end of the test in ohms;

r_1 is the resistance of the coil at the beginning of the test in ohms;

t_1 is the room temperature in degrees C at the beginning of the test;

t_2 is the room temperature in degrees C at the end of the test; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors shall be determined.

7.10.30 As it is generally necessary to de-energize the winding before measuring resistance, determining the value of resistance at shutdown by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown, shall be permitted. A curve of the

resistance values and the time shall be plotted and extrapolated to give the value of resistance at shutdown.

7.10.31 At the conclusion of the test, the temperature rise of each material or component shall comply with 7.10.1.

7.10.32 The temperature rise of a material or component is the difference between its stabilized test temperature and the test ambient.

7.10.33 Protective devices or circuitry shall not trip during the test.

7.10.34 All values for temperature rises specified in Table 15 and Table 17 apply to equipment intended for use in a maximum consistent ambient temperature of 40°C (104°F).

7.10.35 The suitability of insulating materials, other than those in Table 15 and Table 17, shall be determined with respect to properties such as flammability, arc resistance and the like, based on an operating temperature equal to 40°C (104°F) plus the measured temperature rise.

7.10.36 For industrial control equipment rated above 40°C (104°F), the allowable temperature rise for this elevated ambient shall be calculated in accordance with the following formula:

$$TR = TT - [TM - 40°C \ \ (104°F)]$$

where:

TR is the allowable temperature rise;

TT is the maximum temperature rise allowed by Table 15 and Table 17; and

TM is the elevated ambient temperature marked on the equipment.

7.10.37 For industrial control equipment rated below 40°C (104°F), the allowable temperature rise for this reduced ambient shall be calculated in accordance with the following formula:

$$TR = TT + [40°C \ \ (104°F) - TM]$$

where:

TR is the allowable temperature rise;

TT is the maximum temperature rise allowed by Table 15 and Table 17; and

TM is the reduced ambient temperature marked on the equipment.

7.10.38 Immediately following the temperature test, equipment shall be subjected to the dielectric voltage withstand test in Clause 7.11.

7.11 Dielectric voltage withstand test (after normal operating temperature)

7.11.1 While at its maximum normal operating temperature, fire pump control equipment shall withstand for 1 min without breakdown the application of a 60 Hz essentially sinusoidal potential or a direct-current potential:

a) Between uninsulated live parts and the enclosure with the contacts open and closed;

b) Between terminals of opposite polarity with the contacts closed; and

c) Between uninsulated live parts of different circuits.

7.11.2 The test potential shall be the following values for alternating-current, or 1.414 times the following values for direct-current:

a) 500 V – For fire pump control equipment rated not more than 50 V;

b) 1000 V plus twice the rated voltage of the equipment – For fire pump control equipment rated 51 – 600 V; or

c) 2000 V plus 2.25 times maximum rated voltage – For fire pump control equipment rated 601 – 1500 V.

7.11.3 A transformer, a coil, an electronic part, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during the test described in 7.11.1(b).

7.11.4 If the equipment has a meter or meters, they shall be disconnected from the circuit for the dielectric voltage-withstand test described in 7.11.1 and 7.11.2.

7.11.5 Panel meters shall then be tested separately for dielectric strength with an applied voltage of:

a) 1000 V in the case of an ammeter;

b) 1000 V plus twice the rated voltage in the case of any other instrument having a potential circuit;

c) 500 V for meters in circuits operated at 50 V or less (no test requirements are specified for circuits operated at 30 V or less); and

d) 2000 V AC plus 2.25 times the maximum rated voltage for devices rated above 750 V applied between power supply circuits and any non-current-carrying metal parts.

7.11.6 To determine whether equipment complies with the requirements in 7.11, it shall be tested by means of a transformer, the output voltage of which is essentially sinusoidal and can be varied. The applied potential shall be increased from zero to the required value at a substantially uniform rate and as rapidly as is consistent with its value being correctly indicated by a voltmeter. The voltage shall be held at that value for 1 min.

7.11.7 The transformer in 7.11.6 shall either:

a) Have a capacity of 500 VA or larger; or

b) Have a capacity of less than 500 VA, provided a voltmeter is present to directly measure the applied output potential.

7.11.8 A direct-current source shall be used for a direct-current circuit.

7.12 Coated printed circuit board performance test

7.12.1 General

7.12.1.1 To establish pollution degree 1 on a printed-circuit board, samples shall meet the dielectric withstand requirement of 7.12.2.3 and the dielectric breakdown and acceptance criteria of 7.12.2.4 and 7.12.3.5.

7.12.1.2 A total of 20 coated printed-circuit board samples of each base material/coating combination shall be tested. Each sample shall be:

a) Representative of production, containing such items as inks and solder resists if used in the production process;

b) Provided with the minimum creepage distance that is to be used in the final printed-circuit board assembly, using the conductor and coating patterns shown in Figure 2;

c) Provided with the minimum thickness of coating to be used in the final printed-circuit board assembly;

d) Provided with attached lead wires that are suitable for the dielectric test voltage and conditioning temperature; and

e) Prepared by normal production means using the primer or cleaner employed by the end-product manufacturer.

7.12.1.3 Tests shall be conducted on samples of each combination of printed-circuit board base material and coating. Where samples conform to Annex A, item 36 (see Figure 3), then

a) Testing of FR-4 material shall be considered representative of Group 1, comprised of FR-4, FR-5, G-10, G-11, CEM-1, and CEM-3 materials;

b) Testing of XXXPC material shall be considered representative of Group 2, comprised of X, XP, XPC, XX, XXP, XXX, XXXP, and XXXPC materials; and

c) Testing of GPO-2 material shall be considered representative of Group 3, comprised of GPO-2 and GPO-3 materials.

Note: If printed-circuit board base materials conform to Annex A, item 36, testing can then be reduced to an investigation of base materials known to be representative of a specified variety of ASTM type designations having similar construction and/or performance characteristics. The preceding material designations are known to be representative of the indicated ASTM types.

7.12.2 Dielectric strength test

7.12.2.1 Equipment

7.12.2.1.1 Dielectric test equipment shall have an output that is essentially sinusoidal, with a voltage that is adjustable. The transformer shall have a 500 V·A or larger capacity unless provided with a voltmeter that directly indicates the output potential.

7.12.2.2 Method

7.12.2.2.1 Each sample of coated board shall be blanketed with securely positioned aluminum foil or other similar conductive medium. The conductive medium shall completely cover the conductor pattern, except for the insulated lead wire and solder points.

Note: Test electrode removal prevents breakdown at the point of lead connection. An alternative to electrode removal is to insulate the test lead connection points sufficient to prevent breakdown from occurring in these locations. This alternative approach is likely to be taken when a conductive solution is used as a test electrode.

7.12.2.2.2 The test potential shall be applied between the common terminal of each sample and terminals A, B, and C in turn (with the conductive medium in place). The applied test voltage shall be increased from zero to the required value, at a substantially uniform rate that is consistent with the voltage being correctly indicated by the voltmeter used.

7.12.2.3 Dielectric voltage withstand

7.12.2.3.1 Five unconditioned samples shall be subjected to a 1000 V dielectric voltage withstand test between the common test terminal of each test sample and terminals A, B, and C for a period of 1 min without breakdown. Test equipment and method shall be as specified in 7.12.2.1 and 7.12.2.2. Immediately following the dielectric voltage withstand test, unconditioned samples shall be subjected to the dielectric breakdown test of 7.12.2.4.

7.12.2.4 Dielectric breakdown

7.12.2.4.1 The test voltage shall be applied at each point identified in 7.12.2.2.2 and increased until breakdown occurs. The value of the test voltage immediately prior to breakdown shall be recorded.

7.12.3 Sample conditioning

7.12.3.1 General

7.12.3.1.1 The remaining 15 samples shall be divided into three groups of five samples. The three groups shall be conditioned as described in 7.12.3.2, 7.12.3.3, and 7.12.3.4, respectively. Immediately following conditioning, these same samples shall be subjected to a dielectric test voltage that is increased until breakdown occurs. The test voltage shall be applied between the common test terminal of each test sample and each of terminals A, B, and C. The test equipment and the test method shall be those described in 7.12.2.1 and 7.12.2.2. The value of the test voltage immediately prior to breakdown shall be recorded.

7.12.3.2 Environmental conditioning

7.12.3.2.1 General

7.12.3.2.1.1 One set of five samples shall be subjected to three complete cycles of environmental conditioning as described in 7.12.3.2.2 or 7.12.3.2.3 (as applicable). Following conditioning, each sample shall be subjected to the dielectric breakdown test of 7.12.2.4 and the acceptance criteria of 7.12.3.5.

7.12.3.2.2 Indoor end-use applications

7.12.3.2.2.1 Samples shall be conditioned for 24 h at a temperature T (where T is 60°C (140°F) or the rating of the printed wiring board base material, whichever is greater), followed by 96 h at 35 ±2°C (95 ±3.6°F) and 90 ±5% relative humidity, followed by 8 h at 0 ±2°C (32 ±3.6°F).

7.12.3.2.3 Outdoor end-use applications

7.12.3.2.3.1 Samples shall be conditioned by the application of distilled water to a maximum depth of 3 mm over the coated area, for a period of 24 h at 25 ±2°C (77 ±3.6°F), followed by 96 h at 35 ±2°C (95 ±3.6°F) and 90 ±5% relative humidity, followed by 8 h at -35 ±2°C (-31 ±3.6°F).

7.12.3.3 Humidity

7.12.3.3.1 One set of five samples shall be conditioned for 7 d in a test chamber at a temperature of 35 ±1°C (95 ±1.8°F) and 90 ±5% relative humidity. The test samples shall be individually removed from the test chamber and subjected to the dielectric breakdown test of 7.12.2.4 and the acceptance criteria of 7.12.3.5, with breakdown testing beginning less than 2 min after sample removal from the test chamber.

7.12.3.4 Thermal

7.12.3.4.1 One set of five samples shall be conditioned at an oven temperature from the appropriate thermal endurance profile curve of Figure 3. The test time shall be 1000 h, except that a shorter or longer time at a higher or lower temperature respectively (from the same thermal endurance profile curve) may be employed if agreeable to the submitter and the testing agency. The minimum test time shall be 300 h. After thermal conditioning, each sample shall be cooled for 40 h at a temperature of 23 ±2°C (73.4 ±3.6°F) and a relative humidity of 50 ±5%. Upon completion of cooling, each sample shall be subjected to the dielectric breakdown test of 7.12.2.4 and the acceptance criteria of 7.12.3.5.

7.12.3.5 Acceptance criteria

7.12.3.5.1 The results of the test shall be acceptable if the average breakdown value obtained from each set of samples after conditioning is not less than 50% of the average breakdown value of the unconditioned samples.

7.13 Test for controllers with single-phase start protection

7.13.1 A controller for an electric motor driven fire pump shall be connected to a motor rated not less than 3.7 kW (5 hp) to verify operation as specified in 7.13.2 – 7.13.3.

7.13.2 With the motor not running, each phase of the power supply to the controller shall be interrupted, in turn, to verify the controller does not start the motor.

7.13.3 With the motor running, each phase of the power supply to the controller shall be interrupted, in turn, to verify that the motor continues to run.

7.14 Preshipment

7.14.1 All controllers shall be completely assembled, wired, and tested by the manufacturer before shipment from the factory. Controllers shipped in sections shall be completely assembled, wired, and tested by the manufacturer before shipment from the factory.

7.14.2 Such controllers shall be reassembled in the field, and the proper assembly shall be verified by the manufacturer or designated representative.

In Canada, the requirements of 7.14.2 do not apply.

7.15 Controller functionality tests

7.15.1 The electric controller shall be connected to an unloaded 5 hp rated motor or larger and tested for proper functionality as specified in this standard. All responses, sequences, signals, and alarms shall be exercised and shall operate correctly as intended. If the controller is equipped with a transfer switch, it shall also be verified for proper operation as specified in this standard. Testing shall be conducted in an ambient within the range of 5 – 40°C (41 – 104°F).

7.15.2 The diesel controller shall be connected to a diesel engine or an acceptable test simulator and a set of batteries. All responses, sequences, signals, and alarms shall be exercised and shall operate correctly as intended. Each engine terminal shall carry the maximum loads as defined in Annex A, item 40. Testing shall be conducted in an ambient within the range of 5 – 40°C (41 – 104°F).

7.16 Emergency run mechanism

7.16.1 For low voltage controllers (600 VAC or less) an electrical assist shall be required. For medium/high voltage controllers (greater than 600 VAC), the speed of the manual emergency mechanical operator shall be at least equal to the speed of the automatic electrical closing. To determine the manual operation time, the equipment shall be operated 15 times manually under no-load conditions in accordance with the manufacturer's instructions and with any electrical assist devices disconnected.

7.17 EMC requirements

7.17.1 Fire pump controllers shall be suitable for use in environment A or/and B in accordance with Annex A item 41. EMC requirements shall be verified by the tests in accordance with Annex A, item 41.

8 Limited Service Controllers For Electric Motor Driven Fire Pumps

8.1 General

8.1.1 A limited service controller shall consist of an automatic controller for across-the-line starting of squirrel cage motors rated 22 kW (30 hp) or less, and 600 V or less.

8.1.2 Limited service controllers shall comply with the requirements specified in Clauses 1 to 6 as modified by 8.1.3 to 8.1.5.

8.1.3 The manually operated isolating switch specified in 6.14 is not required.

8.1.4 A limited service controller shall have a short circuit current rating of not less than 10,000 A.

8.1.5 A limited service controller shall comply with the marking requirements specified in Clause 16.

9 Residential Fire Pump Controllers

9.1 General

9.1.1 A residential fire pump controller shall consist of an automatic across-the-line controller intended for starting, stopping and protecting squirrel cage motors rated 240 Vac single-phase. These controllers shall be rated for connection to a single-phase alternating current source of supply.

9.1.2 Residential fire pump controllers shall comply with the requirements specified in Clauses 1 to 6 as modified by 9.1.3 to 9.1.18.

9.1.3 One method to achieve the motor overcurrent protection specified in 6.15.3 (b) and 6.16.1 for residential fire pump controllers supplied on the line side of the house main electrical disconnect is to use an inverse time nonadjustable circuit breaker evaluated in accordance with Annex A, item 8, having a standard rating between 150 percent and 250 percent of the motor full-load current.

9.1.4 For controllers supplied on the load side of the main house service, the circuit breaker and locked rotor requirements of Clause 6.15 and 6.16 are not required.

9.1.5 The manually operated isolating switch specified in 6.14 is not required.

9.1.6 The means to read all line currents and all line voltages on the exterior of the controller, as specified in 6.9.1, is not required.

9.1.7 The pressure recording device specified in 6.20.2.4 is not required.

9.1.8 A visible indicator shall monitor the availability of power in all phases, and neutral conductor continuity when the neutral conductor is provided, at the line terminals of the motor starting means. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

9.1.9 Controllers shall detect the loss of any power phase, or neutral conductor continuity when the neutral conductor is provided, regardless of whether the motor is running or not. See 7.6.

9.1.10 As a result of the tests specified in 7.6.2 and 7.6.3, the visual indicators in 6.19.1 shall indicate the loss of any power phase, or neutral conductor continuity when the neutral conductor is provided, and the contacts in 6.19.5 shall change state.

9.1.11 A residential fire pump controller shall have a short circuit rating of not less than 10,000 A.

9.1.12 In Mexico and the United States, when the controller is intended to be connected on the line side of the main circuit breaker, it shall be suitable for use as service equipment.

In Canada, this requirement does not apply.

9.1.13 The requirements related to the system pressure switch specified in clauses 6.20.2.1 and 6.20.2.4 shall not apply.

9.1.14 A residential fire pump controller shall be provided with a pressure switch in accordance with Annex A, item 9.

9.1.15 Instructions for the field adjustment of the pressure switch required during set-up shall be attached to the pressure switch.

9.1.16 In Canada, a separate service box is required.

In Mexico and the United States, this requirement does not apply.

9.1.17 All control circuits shall be rated not more than 240 V.

9.1.18 A residential fire pump controller supplied on the line side of the house main electrical disconnect shall have either an enclosure-door that is lockable or requires use of a tool to open, or a main disconnect or circuit breaker switch having an external handle interlocked with the door to reduce the likelihood of entrance to the enclosure without the disconnect or circuit breaker being in the off position.

9.1.19 The requirements for non-automatic controllers specified in Clauses 6.12, 6.20.1.1, 6.21, and 6.22.3 shall not apply.

9.2 Visible indicators

9.2.1 A visible indicator shall be provided to indicate that power is available. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

9.3 Marking

9.3.1 A residential fire pump controller shall comply with the marking requirements specified in 16.1 – 16.4, 16.7, 16.11, 16.13 – 16.16, and 16.19 – 16.20.

10 Medium Voltage Fire Pump Controllers (Rated Over 600 V)

10.1 General

10.1.1 A fire pump controller rated over 600 V shall comply with the requirements specified in 1 – 6.1, 6.10 – 6.12, 6.14, 6.16 – 6.22, 7.6, 7.8, 7.10, 7.12, and the medium voltage equipment shall comply with the requirements specified in Annex A, item 5.

10.1.2 A medium voltage fire pump controller shall consist of an automatic or non-automatic controller for starting squirrel cage motors rated over 600 V AC.

10.2 Meters

10.2.1 Means shall be provided on the exterior of the controller to read all line currents and all line voltages within ±5 percent of full scale.

10.3 Isolation switch

10.3.1 Provisions shall be made to prevent the isolation switch from being opened or closed under load conditions as specified in Annex A, item 5.

10.3.2 The isolation switch is not required to be interlocked when a load-break disconnecting means complying with the requirements of Annex A, item 21, and having suitable fault closing (short circuit) and interrupting current (load break) and continuous current based on the motor load is provided.

10.4 Pressure-activated device

10.4.1 A pressure-activated device shall be located in a separate compartment of a medium voltage controller so as to reduce the risk of water leakage from coming in contact with high-voltage components.

10.5 Control circuits

10.5.1 A low voltage control circuit shall be supplied from the high-voltage source through a step-down control circuit transformer protected by high-voltage fuses rated for the circuit involved. The secondary of the transformer shall be grounded to the enclosure unless all devices connected are rated for the line voltage. The current supply shall be interrupted when the isolating switch is in the open position.

10.6 Visible indicators

10.6.1 A visible indicator shall be provided to indicate that power is available in all phases. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

10.7 Disconnecting means

10.7.1 The disconnecting means (contactor and isolation means) shall be in accordance with Annex A, item 5.

10.7.2 The medium voltage fuses provided in accordance with Annex A, items 1 and 5, shall be sized to hold 600 percent of the full-load current rating of the motor for at least 100 s.

10.7.3 A complete set of spare fuses shall be supplied with the controller. A compartment or rack shall be provided within the controller enclosure for storage of the replacement set of fuses.

10.8 Emergency run mechanical control at controller

10.8.1 The controller shall comply with the requirements for emergency run mechanical control at the controller as described in 6.21.3.

10.8.2 The mechanical latching described in 6.21.3 may latch automatically. The motor protection specified in 6.16, Locked rotor overcurrent protection, may be inoperable when this mechanical latch is engaged.

10.9 Locked rotor overcurrent protection

10.9.1 Tripping of the locked rotor overcurrent device required by 6.16 may be accomplished by opening the motor contactor coil circuit(s) to drop out the contactor.

10.9.2 Means shall be provided to restore the controller to normal operation by an external manually reset device.

10.10 Performance

10.10.1 The controller shall comply with 6.16 and with the performance requirements of Annex A, item 5.

10.10.2 The emergency run mechanical operation mechanism shall comply with all the performance requirements of Annex A, item 5, when operated manually, independent of the speed of the manual operation.

10.11 Ratings

10.11.1 The controller shall also be rated in accordance with Annex A, item 5.

10.12 Markings

10.12.1 The controller shall comply with the marking requirements specified in with Annex A, item 5, and with 16.3, 16.4, 16.8, 16.9, and 16.12.

11 Controllers With Automatic Transfer Switches For Electric Driven Fire Pumps (600 V Maximum)

11.1 General

11.1.1 An automatic transfer switch that complies with the requirements for fire pump circuit applications in Annex A, item 11, may be provided as part of the fire pump controller assembly housed in a barriered compartment of the controller enclosure or in a separate enclosure attached to the controller.

11.2 Isolating switch

11.2.1 An isolating switch complying with 6.14, located within the automatic transfer switch enclosure or compartment, shall be provided on the line side of the alternate input terminals of the transfer switch and shall be suitable for the available short circuit of the alternate source.

11.2.2 In Canada, the isolating switch provided in a fire pump transfer switch complying with Annex A, item 11, meets the requirement of 11.2.1.

In Mexico and the United States, this requirement does not apply.

11.3 Circuit breaker

11.3.1 A circuit breaker complying with 6.15 and locked rotor protection complying with 6.16 shall be provided in the alternate/emergency side.

11.4 Sensing and signal devices

11.4.1 Turning off the normal source isolating switch or the normal source circuit breaker shall not inhibit the transfer switch from operating. An automatic transfer switch shall be provided with undervoltage sensing devices to monitor all ungrounded lines of the normal power source. Voltage shall be sensed at the load terminals of the fire pump controller circuit breaker. When the voltage on any phase at the load terminals of the circuit breaker within the fire pump controller falls below 85 percent of motor rated voltage, the transfer switch shall automatically initiate starting of the generator, if provided and not running, and initiate transfer to the alternate source. When the voltage on all phases of the normal source returns to within acceptable limits, the fire pump controller may be retransferred to the normal source. Phase reversal of the normal source power shall cause a simulated normal source power failure upon sensing phase reversal.[12)]

[12)] 11.4.1 originated in part from 10.8.3.6.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

11.4.2 Voltage- and frequency-sensing devices shall be provided to monitor all ungrounded conductors of the alternate power source. Transfer to the alternate source shall be inhibited until there is adequate voltage and frequency to serve the fire pump load.

11.4.3 Where the alternate source is provided by a second utility power source and the transfer switch is of a design such that it is not compatible for use with both a generator and second utility, the combination fire pump controller/transfer switch shall be marked in accordance with 16.22.[13)]

[13)] 11.4.3 originated from 10.8.3.7.3 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

11.4.4 Where the combination fire pump controller/transfer switch is marked to indicate that the alternate source is provided by a second utility power source, the requirements of 11.4.2 shall not apply, and undervoltage-sensing devices shall monitor all ungrounded conductors in lieu of a frequency-sensing device.[17)]

11.4.5 Two visible indicators shall be provided to indicate the power source to which the fire pump controller is connected.

11.4.6 When the alternate isolating switch and/or alternate circuit breaker is in the open position, monitoring means shall operate an audible and visual signal on the fire pump controller/automatic transfer switch combination and provide means to actuate a signal at a remote point where required. When interlocked, monitoring of only the circuit breaker shall be required.

11.5 Transfer between sources

11.5.1 Means shall be provided to delay retransfer from the alternate source of power to the normal source until the normal source is stabilized. This time delay shall be automatically bypassed if the alternate source fails.

11.5.2 Means shall be provided to prevent higher than normal inrush currents when transferring the fire pump motor from one source of supply to the other.

11.5.3 The use of an “in-phase monitor” or an intentional delay by means of an open neutral position of the transfer switch to comply with the requirements of 11.5.2 shall be prohibited.[14)]

[14)] 11.5.3 originated from 10.8.3.10.1 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

11.5.4 The fire pump transfer switch shall not have integral short circuit, ground-fault or overcurrent protection as part of the switching mechanism of the transfer switch.[15)]

[15)] 11.5.4 originated from 10.8.3.11 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

11.5.5 The following shall be provided:

a) A device to delay starting of the alternate source generator to reduce the likelihood of nuisance starting in the event of momentary dips and interruptions of the normal source.

b) A circuit loop to the alternate source generator whereby either the opening or closing of the circuit will start the alternate source generator (when commanded by the transfer switch).

c) A means to prevent sending the signal for starting of the alternate source generator (when commanded by the transfer switch), when the isolation switch or circuit breaker (if installed) on the alternate source side of the transfer switch is open.

d) Auxiliary contacts (open, closed or both), mechanically actuated by the transfer switch mechanism, shall be provided to indicate whenever the alternate source is the source supplying power to the controller.

11.6 Test switch

11.6.1 An externally operable momentary test switch shall be provided on the enclosure to simulate a normal power source failure.

11.7 Ratings

11.7.1 The fire pump transfer switch shall have an ampere or hp rating not less than 115 percent of the equivalent motor full-load current (refer to Table 2 and Table 3) and shall also be suitable for switching the motor locked rotor current.

11.7.2 A transfer switch shall have a short circuit withstand rating equal to or greater than that of the controller or be adequate to provide the short circuit rating of the controller, as determined by testing per 7.1.

12 Diesel Engine Drive Controllers

12.1 General

12.1.1 A diesel engine drive controller may be an automatic or a non-automatic type for diesel engine driven fire pumps; and shall comply with the requirements in Clauses 1 – 6.5 and 6.20.2.

12.1.2 A voltmeter with an accuracy of ±5 percent shall be provided for each battery bank to indicate the voltage during cranking.

12.1.3 The DC power supplies for starting the engine shall be two separate battery banks requiring two independent charging circuits complying with Annex A, item 13.

12.1.4 Essential loads, including the engine, controller, and all pump equipment combined, shall not exceed 0.5 ampere each for a total of 1.5 amperes, on a continuous basis.

12.2 Locked enclosure

12.2.1 All switches required to keep the controller in the automatic position shall be located within a lockable enclosure and visible through a breakable, transparent cover or breakable glass panel.

12.3 Field wiring terminals

12.3.1 Field wiring terminals shall comply with 6.4 and shall be suitable for the field wiring of stranded type conductors.

12.3.2 Diesel engine fire pump controllers may supply essential and necessary AC and/or DC power to operate pump room dampers, engine oil heaters and other associated required engine equipment only when provided with factory-equipped dedicated field terminals and overcurrent protection.

12.3.3 A diesel engine fire pump controller terminal block arrangement to facilitate connection of the controller to the engine shall include, as necessary, the terminals referenced in Figure 4. Also see Table 19.

12.4 Starting and control

12.4.1 An automatic controller shall also be operable as a non-automatic controller.

12.4.2 The primary source of power for a diesel engine drive controller shall be from the engine starting batteries.

12.4.3 Upon receiving a signal to start, the controller shall crank the engine first from one battery and then from the other (two batteries shall be supplied with the engine) on successive starting attempts. The "attempt to start" sequence shall be fixed and shall consist of six crank periods of 15 seconds each separated by rest periods of 15 seconds duration.

12.4.4 The controller shall be in a fully functional state within 10 seconds upon application of DC power.

12.4.5 In the event that one battery is inoperative or missing, the controller shall lock-in on the remaining battery unit during the cranking sequence.

12.4.6 In the event that the controller has not received a signal that the engine is running by the end of the "attempt to start" sequence, the controller shall stop all further cranking and operate a visible indicator and audible alarm on the controller.

12.4.7 Terminal 1 power shall be energized anytime the engine is operating from manual or automatic from the controller.

12.4.8 Manual crank buttons shall only be operable in manual modes.

12.5 Alarm and signal devices

12.5.1 All visible indicator alarms shall be plainly visible to the operator.

12.5.2 Combined manual and automatic controllers shall have a visible indicator to indicate that the controller is in the automatic position and a separate visible indicator to indicate that the controller is in the manual position. When the visible indicator is a pilot lamp, it shall be accessible for replacement.

12.5.3 Separate visible indicators and a common audible alarm capable of being heard while the engine is running and operable in all positions of the main switch except the off position shall be provided to immediately indicate trouble caused by the following conditions:

a) Critically low oil pressure in the lubrication system. The controller shall provide means for testing the low oil pressure alarms and circuit in conjunction with the engine circuit testing method.

Note: The pressure switch may be tested by activating the low oil pressure light while the engine is cranking without sounding the system failure alarm.

b) High engine temperature.[16)]

c) Failure of engine to start automatically.

d) Shutdown from overspeed.

e) Battery failure or missing battery. Each controller shall be provided with a separate visible indicator for each battery. The battery failure signal shall initiate at no lower than two thirds of battery nominal voltage rating (8.0 V DC on a 12 V DC system). Sensing shall be delayed to prevent nuisance signals.

f) Battery charger failure. Each controller shall be provided with a separate visible indicator for battery charger failure and shall not require the audible alarm for battery charger failure. Manual isolation of battery chargers constitutes a battery charger failure and shall be visibly alarmed.

g) Low air or hydraulic pressure. Where air or hydraulic starting is provided, each pressure tank shall provide to the controller separate visible indicators to indicate low pressure.

h) System overpressure, for engines equipped with pressure limiting controls, to actuate at 115 percent of set pressure.

i) Electronic/engine control module (ECM) selector switch in alternate position (for engines with ECM controls only).

j) Fuel injection malfunction (for engines with ECM only).

k) Low fuel level signal.

l) Low engine temperature.[17)]

m) Supervisory signal for interstitial space liquid intrusion.[17)]

n) High cooling water temperature.[17)]

o) Loss of electrical continuity through engine starting contactors.

p) Loss of DC power.

q) Low suction pressure, for engines equipped with low suction pressure limiting controls.

[16)] Item (b) of 12.5.3 originated from 12.4.1.3 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

[17)] Items (l), (m) and (n) of 12.5.3 originated from 12.4.1.4 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.4 A separate signal silencing switch or valve, other than the controller main switch, shall be provided for the conditions specified in 12.5.3.[18)]

[18)] 12.5.4 originated from 12.4.1.5 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.5 The switch or valve shall allow the audible device to be silenced for up to 4 hours and then re-sound repeatedly for the conditions in items (a) – (d) of 12.5.3.[19)]

[19)] 12.5.5 originated from 12.4.1.5.1 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.6 The switch or valve shall allow the audible device to be silenced for up to 24 hours and then re-sound repeatedly for the conditions in items (e) – (n) of 12.5.3.[20)]

[20)] 12.5.6 originated from 12.4.1.5.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.7 The audible device shall re-sound until the condition is corrected or the main switch is placed in the off position.[21)]

[21)] 12.5.7 originated from 12.4.1.5.3 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.8 The controller shall automatically return to the nonsilenced state when the alarm(s) have cleared (returned to normal).[22)]

[22] 12.5.8 originated from 12.4.1.6 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.9 The switch specified in 12.5.4 shall be clearly marked as to its function.[23]

[23] 12.5.9 originated from 12.4.1.6.1 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.10 In addition to those conditions that require signals for pump controllers and engines, there are other optional signals that may be used, depending upon local conditions. If provided these signals shall be silenceable. Some of these conditions are as follows, but are not limited to:

a) Low pump room temperature,

b) Relief valve discharge,

c) Flowmeter left on, bypassing the pump,

d) Water level in suction supply below normal, and

e) Water level in suction supply near depletion.[24]

[24] 12.5.10 originated from 12.4.1.7 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.5.11 The circuit shall be arranged so that the audible signal will be actuated if the silencing switch or valve is in the silent position when the supervised conditions are normal.[25]

[25] 12.5.11 originated from 12.4.1.8 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.6 Auxiliary contacts for remote sensors

12.6.1 Controllers shall be equipped with contacts (open, closed, or both) to operate circuits to indicate each of the following conditions:

a) Engine running;

b) The controller main switch has been turned to "off" or "manual" position;

c) Trouble on the controller or engine (separate or common signals);

d) Loss of total power (AC and DC). This may be provided by contacts in either (b) or (c) above.

If DC battery power is lost, the relay shall be held energized and shall drop out to alarm. An audible alarm shall be provided and powered from the AC supply.

12.7 Pressure recorder

12.7.1 The controller shall be equipped with a pressure recording device to sense and record the pressure in each fire pump controller pressure sensing line at the input to the controller. The pressure recording device shall operate continuously for at least 7 d without resetting or rewinding. The pressure recording device shall not be solely dependent upon AC electric power as a power source. Upon loss of AC electric power, the pressure recording device shall be capable of at least 24 h of additional operation.

12.7.2 This device shall be responsive to water pressure in the fire protection system. The pressure sensing element of the device shall be capable of a momentary surge pressure of 2,758 kPa (400 psi) or 133 percent of fire pump controller rated operating pressure, whichever is higher, without losing its accuracy.

12.8 Weekly program timer

12.8.1 The controller equipment shall be arranged to automatically start and run the engine for at least 30 min once a week. A solenoid valve drain on the pressure control line shall be the initiating means.

12.8.1.1 Means shall be permitted within the controller to manually terminate the weekly test, provided a minimum of 30 min has expired.[26)]

[26)] 12.8.1.1 originated from 12.7.2.7.3 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.8.2 The solenoid valve drain is not required to be the initiating means for a non-pressure-activated controller.

12.9 Automatic controllers

12.9.1 Water pressure control

12.9.1.1 There shall be provided a pressure-activated switch having adjustable high and low calibrated set-points as part of the controller. There shall be no pressure snubber or restrictive orifice employed within the pressure device. This device shall be responsive to water pressure in the fire protection system. The pressure sensing element of the device shall be capable of a momentary surge pressure of 2,758 kPa (400 psi) or 133 percent of fire pump controller rated operating pressure, whichever is higher, without losing its accuracy.

12.9.1.2 The pressure-activated device and solenoid valve are not required to be provided on a non-pressure-activated controller.

12.9.1.3 The requirements of 6.20.2 apply.

12.9.2 Fire protection equipment control

12.9.2.1 Controllers with provision to supply special water control equipment (deluge valves, dry pipe valves, etc.) may start the motor before the pressure-activated switch(es) would do so. The controller shall be equipped to start the engine upon operation of the fire protection equipment. The starting sequence of the controller shall be initiated by the opening of the control circuit loop containing the remote equipment.

12.9.2.2 Sequence starting of multiple pumps: The controller for each unit of multiple pump units shall incorporate a sequential timing device to prevent any one driver from starting simultaneously with any other driver. If water requirements call for more than one pumping unit to operate, the units shall start at intervals of 5 to 10 s. Failure of a leading driver to start shall not prevent subsequent drivers from starting.

12.9.3 External circuits connected to controllers

12.9.3.1 With pumping units operating singly, or in multiple, the control circuits entering or leaving the fire pump controller and intended to extend outside the fire pump control room shall be so arranged as to prevent failure to start due to fault. Breakage, disconnecting, shorting of the wires, or loss of power to these circuits may cause continuous running of the fire pump, but shall not prevent the controller(s) from starting the fire pump(s) due to causes other than these external circuits.

12.9.4 Sole supply pumps

12.9.4.1 A controller intended for use with a sprinkler or standpipe system where an automatically-controlled pumping unit constitutes the sole supply shall be arranged for manual shutdown in 6.22.1.

12.9.5 Non-pressure switch actuated automatic controller

12.9.5.1 A non-pressure switch actuated automatic controller shall be activated by a remote sensor, such as a smoke detector, fire alarm, carbon monoxide detector, or other such device. A pressure switch shall not be required.

12.9.5.2 The starting sequence of the controller shall be initiated by the opening of the remote contact(s) of the device in 12.6.1.

12.9.5.3 No other means of stopping the fire pump motor shall be provided except for those on the controller.

12.10 Non-automatic controller

12.10.1 For a manual electric control at the controller, there shall be a manually operated switch on the controller panel. This switch shall be so arranged that the operation of the engine, when manually started, is not affected by the failure of any of the automatic circuits or pressure-activated switch. The arrangement shall also be such that the unit remains in operation until manually shut down.

12.11 Methods of stopping

12.11.1 Manual electric stopping

12.11.1.1 Manual stopping shall be accomplished by either of the following:

a) Operation of the main switch to the off position as located in 12.2.1; or

b) Operation of a stop button located on the outside of the controller enclosure.

12.11.1.2 Manual stopping shall cause the engine shut down through the automatic standby circuits only when all starting causes have been returned to normal. The controller shall then return to the full automatic position.

12.11.1.3 When the controller has a means for connection of a circuit for the remote starting of the fire pump, this means shall be such that the fire pump engine is not capable of being stopped from the remote station.

12.11.2 Automatic stopping after automatic start

12.11.2.1 When the controller is set up for automatic engine stopping, the controller shall stop the engine only after all starting causes have returned to normal and a 30 min minimum run time has elapsed.

12.11.2.2 Means shall be provided to disable automatic stopping. A visible indicator shall be provided to indicate that automatic stopping is disabled or enabled.

12.11.2.3 When the engine emergency overspeed device operates, the controller shall remove power from the engine running devices, prevent cranking, energize the overspeed alarm, and lock out until manually reset. Resetting of the overspeed circuit shall be required at the engine and by resetting the controller main switch to the off position. The controller shall not be capable of being reset until the engine overspeed stopping device is manually reset.

12.11.2.4 The engine shall not shut down automatically on high engine temperature, low oil pressure, or high cooling water temperature when any automatic starting or running cause exists. If no other starting or running cause exists during engine test, the engine shall shut down automatically on high water temperature, low oil pressure, or high cooling water temperature. If after shutdown a starting cause occurs, the controller shall restart the engine and override the high engine temperature, low oil pressure, or high cooling water temperature shutdowns for the remainder of the test period.[27)]

[27)] 12.11.2.4 originated from 12.7.5.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

12.12 Emergency control

12.12.1 Automatic control circuits, the failure of which could prevent engine starting and running, shall be completely bypassed during manual start and run.

12.12.2 A diesel engine drive controller shall comply with the marking requirements of 16.2(e).

13 Controllers For Additive Pumps

13.1 General

13.1.1 An additive pump controller shall comply with the requirements in Sections 1 – 6, and with the requirements specified in Clauses 13.2 – 13.6.

13.2 Automatic starting

13.2.1 In lieu of the pressure-activated switch described in 6.20.2.1, an additive pump controller shall be provided with means for automatic activation by either a remote normally open contact or a remote normally closed contact.

13.2.2 When the pressure-activated switch described in 6.20.2.1 is provided, the controller shall comply with 6.20.2.5 and 6.20.2.6.

13.3 Dump valves

13.3.1 Diesel engine drive control automatic operation

13.3.1.1 When a diesel driver is used in conjunction with a positive displacement pump having an electrically operated dump valve, the controller shall provide a means to activate and then close the dump valve after successful engine start has been attained.

13.3.1.2 The means shall consist of circuitry and terminals for connecting the dump valve solenoid coil.

13.3.1.3 The dump valve solenoid shall be energized by engine battery power.

13.3.1.4 The controller circuitry shall cause the dump valve to open to unload the pump, prior to or concurrent with the first engine cranking cycle.

13.3.1.5 The controller shall provide a timing means to actuate and then close the dump valve after engine start is finished.[28)] The timing means shall actuate upon crank disconnect.

[28)] 13.3.1.5 originated from 12.7.2.5.4 of the 2010 edition of NFPA 20. Reprinted with permission from NFPA 20-2010, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2009, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

13.3.2 Electric motor drive control automatic operation

13.3.2.1 When an electric motor driver is used in conjunction with a positive displacement pump having an electrically operated dump valve, the controller shall provide a means to activate and then close the dump valve after the motor has full voltage.

13.3.2.2 The means shall consist of circuitry and terminals for connecting the dump valve solenoid coil.

13.3.2.3 The controller shall provide suitable voltage for the dump valve solenoid. Said power shall not exceed 240 V AC.

13.3.2.4 The controller circuitry shall cause the dump valve to open to unload the pump, prior to or concurrent with motor power being applied.

13.3.2.5 The controller circuitry shall allow the motor to reach full speed and full power capability before closing the dump valve.

13.4 Methods of stopping

13.4.1 When a controller is arranged for automatic stopping as described in 6.22.2, the timer shall be set to less than 10 min, but not less than 1 min, for an additive pump controller.

13.5 Manual operation

13.5.1 Means shall be provided at the controller to ensure dump valve operation during manual start.

13.6 Lockout

13.6.1 When the additive pump controller contains a lockout feature to stop the additive pump motor, the lockout shall be indicated by a visible indicator and shall be provided with means to annunciate the condition at a remote location.

14 Variable Speed Fire Pump Controllers

14.1 General

14.1.1 A variable speed electric motor driven fire pump controller (VSEFPC) shall comply with the requirements of Sections 1 – 6, and with the requirements specified in 14.2 – 14.11. Each VSEFPC shall consist of a full and complete fire pump controller which constitutes the "bypass" power path and a variable speed power path (VSPP), with or without automatic transfer switch.

14.1.2 Both the bypass path and the VSPP path shall have a kW (hp) rating at least equal to the motor kW (hp) or, where rated in amperes, shall have an ampere rating not less than the motor full-load current. The VSPP path shall consist of a Variable Frequency Drive (VFD) unit and other components as specified in 14.4.

14.2 Environmental

14.2.1 The controller shall be marked with the maximum ambient temperature rating; this temperature rating shall not be less than +40°C (+104°F).

14.2.2 When the temperature test is conducted in accordance with 7.10, the VSPP shall be evaluated for suitability at the rated ambient temperature.

14.2.3 When the temperature test is conducted, particular attention shall be given to the following components, specifically, that their maximum rated temperature shall not be exceeded:

a) The VFD variable speed drive;

b) The line reactor;

c) The DC link reactor (choke), when used;

d) The motor reactor, when used; and

e) The motor filter (dV/dT filter), when used.

14.2.4 Means shall be provided to prevent the fire pump controller internal temperature from exceeding the temperature rating of the VFD.

14.2.5 The cooling means shall be suitable for the application and shall not compromise the enclosure Type rating of the fire pump controller. Air conditioning shall not be permitted.

14.2.6 Pollution degree 2 shall be maintained for the VFD.

14.2.7 The VFD shall be mounted in, as a minimum, a Type 12 enclosure(s). In addition, the enclosure(s) shall be permitted to be marked with an ingress protection (IP) rating of IP54 in accordance with Annex A, item 42.

14.2.8 The controller shall be marked with the total, maximum heat dissipation in either BTU or watts.

14.3 Power components

14.3.1 The bypass path shall meet all the requirements of a complete electric fire pump controller.

14.3.2 Circuit protection

14.3.2.1 The VSPP circuit shall employ circuit protection complying with 14.3.2.2.

14.3.2.2 The circuit protection shall comply with 14.3.2.3 for proper operation at each controller rated horsepower and voltage. Proper operation shall consist of the VSPP circuit protection opening the VSPP before tripping of the fire pump circuit breaker.

14.3.2.3 The circuit protection specified in 14.3.2.2 shall be selectively coordinated with the circuit breaker, and with the isolating switch, if of the self-protecting type.

14.3.2.4 This circuit protection shall operate within 30 min at 300% and within 7 seconds at 600% of motor FLA.

Note: VFDs are self-protected only in regards to their output circuitry when fully functional.

14.3.2.5 The circuit protection specified in 14.3.2.2 shall be installed on the line side of any other components in the VSPP path.

Note: This is so as to prevent the fire pump circuit breaker or isolating switch from tripping in the event of a short circuit anywhere in the VSPP circuitry, wiring, or components.

14.3.2.6 The circuit protection specified in 14.3.2.2 shall provide protection for the VFD if the VFD requires circuit protection to support the short circuit rating of the fire pump controller.

14.3.2.7 The coordination shall be in addition to that required to prevent the controller circuit breaker from tripping due to any fault in the VSPP path.

14.3.2.8 The short circuit rating of the controller is the lesser of the short circuit withstand capability of the bypass path and the VSPP path.

14.3.2.9 Where fuses are used as circuit protection, they shall comply with 14.3.2.10 – 14.3.2.13.

14.3.2.10 There shall be one fuse in each ungrounded conductor circuit.

14.3.2.11 The fuses shall comply with the requirements of Annex A, items 24 to 32, and the fuse holder shall comply with the requirements of Annex A, items 33 and 34.

14.3.2.12 The fuses (fuseholder) shall be readily accessible for replacement.

14.3.2.13 A complete set of spare fuses shall be supplied with the controller.

14.3.2.14 There shall be a marking provided near the fuseholder specifying the class [type], amp, and volt rating of the fuse.

14.3.3 The VFD shall be provided with a contactor on its line and load side for isolation.

14.3.3.1 The contactors of 14.3.3 shall comply with 6.17.1.

14.3.3.2 The VFD load side contactor shall be mechanically and electrically interlocked with the bypass contactor(s).

Note: This is to prevent the bypass contactor from back feeding power to the VFD output circuit.

14.3.4 A line reactor rated for continuous duty shall be provided. It shall be installed ahead of the VFD and shall have a 5 percent impedance rating as a minimum.

Note 1: This is to reduce the likelihood of capacitor and rectifier damage and to avoid capacitor overvoltage shutdown of the VFD and to reduce the input current harmonics to near sinusoidal to avoid overheating the VFD input circuit components and wiring. This reactor is required whether or not the controller or its VFD also contain a DC link reactor, choke (inductor), or swinging choke. By being ahead of the VFD, it protects both the input rectifiers or SCRs, as well as reducing capacitor current (ripple current) and capacitor over-voltage (and over-voltage trip) in the energy storage capacitors. The line reactor enhances line quality by suppressing line transients and disturbances.
Note 2: A DC link reactor or choke does not protect the input rectifiers or SCRs from line voltage transients.

14.3.5 The horsepower or output rating of the VFD shall be no less than the horsepower or current rating of the controller.

14.3.6 Where installed in a controller to reduce transients, impulses, or harmonics to the motor, a motor (load) reactor or a motor filter (dV/dT filter) shall be rated for continuous duty.

14.4 Control equipment and components

14.4.1 All control devices required to keep the controller in automatic operation shall be within lockable enclosure(s) and/or include adequate password protection means.

14.4.2 The controller shall have a means of setting and displaying the desired system operating parameters, including the set pressure.

14.4.3 The pressure feedback transducer shall be independent of the controller pressure switch or transducer (start and stop operation).

14.4.4 The set pressure point and adjustment means shall be independent of the controller start (pump demand) and stop pressure settings.

14.4.5 Each VSEFPC (fire pump controller) shall have its own pressure feed-back transducer.

14.4.6 The pressure feedback transducer specified in 14.4.5 shall only be used to control the VSEFPC.[29)]

[29)] 14.4.6 originated from 10.10.7.2 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

14.4.7 Each VSEFPC shall operate independently of any common or central control when any demand for the fire pump to operate occurs.

14.4.8 The controller or the VFD shall have suitable pressure sensing and controlling means to control the speed of the pump to maintain the set pressure.

14.4.9 The pressure sensing and controlling means shall have sufficient control of time constants in order to prevent oscillation, hunting, undue overshoot, or undue undershoot of the discharge pressure during starting and running.

14.4.10 The controller shall have means to allow setting gain and time parameters in the field.

14.5 Mode control

14.5.1 The VFD set pressure point will normally be set above the pump start pressure setting. This setting is required whether the controller is set for automatic or manual stop operation.

14.5.2 If the system pressure remains below the start pressure for more than a 15 second period, the bypass operation shall occur.

14.5.3 If the variable speed drive indicates that it is not operational within 5 seconds, the bypass operation shall occur.

14.5.4 The controller shall have readily accessible means, such as a mode switch, to change the operating mode from VSPP operation to bypass operation.

14.5.5 When the manual selection means required in 14.5.4 is used to initiate a switchover from variable speed to bypass mode, if the pump is running in the variable speed mode and none of the conditions in 14.5 that require the controller to initiate the bypass operation exist, the controller shall be arranged to provide a restart delay to allow the fire pump motor to be de-energized before it is re-energized in the bypass mode.[30)]

[30)] 14.5.5 originated from 10.10.3.5 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

14.5.6 The switching means shall be on the outside of the controller and shall be clearly identified.

14.5.7 When the mode switch is set to bypass, all start demands shall start the pump in the bypass mode.

14.5.8 When set to variable speed mode, all start demands shall start the pump in variable speed mode. A specific remote signal may start the pump in bypass mode.

14.6 Motor control

14.6.1 For constant torque loads or positive displacement pumps, the controller may provide a means (such as contacts or switched power) to energize an independent cooling fan or blower to keep the motor from overheating when provided with factory-equipped dedicated field terminals and overcurrent protection.

14.6.2 The factory programming of the VFD parameters shall limit the maximum motor output frequency to the line frequency.

14.7 Signals and alarms

14.7.1 The controller shall be equipped with at least the following visible indicators and individual alarm contacts (open or closed):

a) Drive failure to indicate when the drive has failed;

b) Bypass mode to indicate that the controller is in the bypass; and

c) Overpressure to indicate that the system pressure exceeds 115% of the set pressure.

14.8 Skip frequencies

14.8.1 The VFD shall have means to skip over resonant frequencies (critical speeds), when present, during motor acceleration (ramp up), speed modulation, and, if provided, motor deceleration (ramp down).

14.9 Variable mode operation

14.9.1 Readiness time: The controller, including the VFD, shall be ready for operation and begin accelerating the motor within 10 seconds.

14.9.2 The controller (its VFD) shall allow for restarting of the motor after any of the following conditions:

a) A demand interruption;

b) A power interruption;

c) A transfer switch operation;

d) Operation of the local stop pushbutton; and

e) Transfer of the lockout contacts, if used, to the enable mode.

14.9.3 The controller shall provide positive means to accomplish restarting of the motor without excessive transient or inrush currents.

14.10 Automatic transfer to bypass operation

14.10.1 If, and when, the controller switches automatically to the bypass (full speed) mode it shall remain in that mode, until manually reset.

14.10.2 The bypass switching sequence shall consist of the operations in 14.10.3 – 14.10.5, in that order.

14.10.3 The controller shall cause both isolation contactors to open.

14.10.4 The controller shall pause for a time period of 2 to 4 seconds to allow the motor magnetic field (motor back EMF) to decay to a value that will prevent excessive inrush currents.

14.10.5 The controller shall then restart the fire pump with reduced in-rush starting if provided in the bypass mode.

14.10.6 Automatic shutdown shall be permitted in bypass mode.

14.11 Marking

14.11.1 The controller shall be labeled with or provided with a label for marking the following parameters:

a) The set pressure;

b) The pump start pressure; and

c) The pump stop pressure.

RATING

15 Ratings

15.1 In Canada and the United States, controllers driving electric motor fire pumps shall be rated in volts, horsepower or kilowatts and full load amperes complying with Table 2 and Table 3, frequency, and short circuit current in amperes rms symmetrical. The rating shall indicate whether the equipment is for direct or alternating current. The rating of alternating-current equipment shall include the number of phases.

In Mexico, controllers driving electric motor fire pumps shall be rated in volts, kilowatts, and full load amperes complying with Table 2 and Table 3, frequency, and short circuit current in amperes rms symmetrical. The rating shall indicate whether the equipment is for direct or alternating current. The rating of alternating-current equipment shall include the number of phases.

Note: The rating of equipment obviously intended for single-phase use only is not required to include the number of phases.

15.2 Controllers driving diesel engine fire pumps shall be rated in battery voltage and control power voltage.

15.3 With reference to 6.1.3, the enclosure of a controller shall be rated for the external environmental conditions for which it is found acceptable.

MARKING

16 Markings

16.1 All markings shall be in the appropriate language (or symbols as noted in this standard), as necessary, for the country in which the fire pump controller will be installed. A manufacturer may choose to utilize multiple languages on a fire pump controller.

Advisory Note: In Canada, there are two official languages, English and French, and in Mexico, the official language is Spanish. Annex C provides translations in French and Spanish of the English markings specified in this standard. Markings required by this standard may have to be provided in other languages to conform with the language requirements of the country where the product is to be used.

16.2 Controllers shall be marked where visible after installation with:

a) "Electric Fire Pump Controller" (Clause 6, Clause 10, or Clause 11);

b) "Limited Service Controller" (Clause 8);

c) "Residential Fire Pump Controller for Installation in One- and Two-Family Dwellings and Manufactured Homes in Accordance With NFPA 13D " (Clause 9);

d) In addition to items (a) or (b) or (f), when supplied, "Fire Pump Power Transfer Switch" (Clause 11);

e) “Diesel Engine Fire Pump Controller” (Clause 12); or

f) "Limited Service Additive Pump Controller” or “Electric Additive Pump Controller" (Clause 13).

16.3 Controllers shall also be marked where visible after installation with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is identified;

b) Electrical ratings:

For controllers for electric motors, an additional statement "Suitable for use on a circuit capable of delivering not more than ___ amperes rms symmetrical at __ volts AC." or "___ amperes RMS symmetrical at ___ volts AC short circuit current rating," or the equivalent. The blank spaces shown shall have numbers filled in for each application;

c) The model number;

d) An enclosure type number, indicating the external environmental conditions for which it is intended. See 6.1.3;

e) Rated operating pressure;

f) Rated ambient temperature range; and

g) EMC immunity class A and emission class A or B environment for which it was tested, in accordance with Annex A, item 41. Refer to 7.17 for environment type.

16.4 Complete instructions covering the operation of the controller shall be provided and conspicuously mounted on the controller.

16.5 With reference to 6.14.1, and except as permitted by 16.6, an isolating switch shall be marked on the outside of the enclosure adjacent to the operating handle with the signal word "WARNING" and the following or equivalent statement:

"RISK OF ELECTRIC SHOCK – DO NOT OPEN OR CLOSE THIS SWITCH WHILE THE CIRCUIT BREAKER (DISCONNECTING MEANS) IS IN THE CLOSED POSITION."

16.6 When the isolating switch and the circuit breaker are so interlocked that the isolating switch can neither be opened nor closed while the circuit breaker is closed, the warning label described in 16.5 is not required. When omitted, the label shall be replaced with an instruction label which directs the order of operation.

16.7 The circuit breaker defined in 6.15.2 shall be provided with a nameplate with the legend "CIRCUIT BREAKER – DISCONNECTING MEANS" in letters not less than 10 mm (3/8 inch) high, located on the outside of the controller enclosure adjacent to the means for operating the circuit breaker.

16.8 The fire pump controller and transfer switch shall each have a cautionary marking to indicate that the isolation switches, on both the controller and transfer switch, are to be opened before servicing the controller, transfer switch, or motor.

16.9 In Mexico and the United States, with reference to 6.6.1, controllers shall be marked "Suitable for Use as Service Equipment" on the outside of the controller enclosure. The marking shall be provided separately or as part of the nameplate containing the manufacturer's name or trademark, and other ratings. When provided on a separate label, the marking shall include the manufacturer's name or trademark.

In Canada, this requirement does not apply.

In the United States, controllers marked "Suitable for Use as Service Equipment" shall be additionally marked to reference Article 230 of item 2 of Annex A, for installation requirements.

16.10 In Mexico and the United States, with reference to 6.6.1, when a controller is to be used as service equipment, a separate label containing the marking, "Service Disconnect" shall be shipped loosely with

instructions indicating that the label is to be applied on the outside of the enclosure adjacent to the operating handle of the isolating switch, when provided. When an isolating switch is not provided, the label shall be applied adjacent to the operating handle of the circuit breaker.

In Canada, this requirement does not apply.

16.11 When a controller is intended for outdoor use, a marking shall be provided on the enclosure indicating that the controller is to be used only where the temperature is not less than 4.4°C (40°F).

16.12 In Mexico and the United States, a field-wiring pressure wire connector intended to be used only with copper conductors in accordance with 6.4.5 (a) shall be marked to indicate the use of copper conductors only.

In Canada, this requirement does not apply.

16.13 In Canada, a field-wiring pressure wire connector shall be used only with copper conductors. No marking is required to identify this condition.

In Mexico and the United States, this requirement does not apply.

16.14 An electrical schematic/field connection diagram, indicating all internal wiring, circuits, test terminals, provisions for alarm circuits, all power sources, and other components, shall be permanently attached to the inside of the controller enclosure.

16.15 All the field wiring terminals provided in the controller shall be plainly marked to correspond with the field connection diagram provided with the controller.

16.16 Each operating component of the controller shall be marked to plainly indicate an identifying number referenced on the electrical schematic field connection diagram. The marking shall be located so as to be visible after installation.

16.17 For external diesel engine connections, the field connection terminals shall be commonly numbered between the controller and engine terminals.

16.18 Each accessible enclosure surface in excess of the maximum temperatures specified in Table 17 shall be marked "WARNING – HOT SURFACE – RISK OF BURN", or the equivalent.

16.19 Controllers shall be marked to indicate the temperature rating (60°C only, 60/75 or 75°C only) of the field installed conductors for which the equipment has been investigated. A field-wiring terminal need not be marked to indicate the temperature rating if it is intended for the connection of a control circuit conductor only.

16.20 If a fuse used to determine compliance with item 3 of Table 15 is a Class G or K, there shall be a marking near the fuseholder specifying the class of the replacement fuse.

16.21 The emergency run mechanical control described in 6.21.3, shall be marked as to function and operation.[31)]

[31)] 16.21 originated from 10.5.3.2.4 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

16.22 A combination fire pump controller/transfer switch of a design such that it is not compatible for use with both a generator and second utility shall be marked to indicate that the alternate source shall be provided by a second utility power source.[32)]

[32)] 16.22 originated from 10.8.3.7.3 of the 2013 edition of NFPA 20. Reprinted with permission from NFPA 20-2013, Standard for Installation of Stationary Pumps for Fire Protection, Copyright © 2013, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

16.23 All fire pump controllers shall be provided with a warning marking to alert qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

Routine Tests

17 Routine Tests

17.1 Dielectric withstand testing shall be conducted on 100 percent of production units in accordance with 7.4.

TABLES AND FIGURES

Table 1
Minimum acceptable spacings

(See 6.2.1 and 6.2.4)

Potential involved volts rms AC or DC		Minimum spacings, mm (inch)											
		General equipment						Devices having limited rating (clause 6.2.4)					
		51 – 150		151 – 300		301 – 600		51 – 150		151 – 300		301 – 600	
Between any uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part	Through air or oil	3.0[a]	(1/8)	6.3	(1/4)	9.4	(3/8)	1.5[a]	(1/16)	1.5[a]	(1/16)	4.6[a]	(3/16)
	Over surface	6.3	(1/4)	9.4	(3/8)	12.7	(1/2)	3.0[a]	(1/8)	3.0[a]	(1/8)	9.4	(3/8)
Between any uninsulated live part and the walls of a metal enclosure including fittings for conduit or armoured cable[b]	Shortest distance	12.7	(1/2)	12.7	(1/2)	12.7	(1/2)	6.3	(1/4)	6.3	(1/4)	12.7	(1/2)
NOTES 1 A slot, groove, or the like, 0.33 mm (0.013 inch) wide or less in the contour of insulating material shall be disregarded.													

Table 1 Continued on Next Page

Table 1 Continued

Potential involved volts rms AC or DC	Minimum spacings, mm (inch)					
	General equipment			Devices having limited rating (clause 6.2.4)		
	51 – 150	151 – 300	301 – 600	51 – 150	151 – 300	301 – 600
2 An air space of 0.33 mm (0.013 inch) or less between a live part and an insulating surface shall be disregarded for the purpose of measuring over surface spacings.						
[a] The spacing between field wiring terminals of opposite polarity and the spacing between a field wiring terminal and a grounded dead metal part shall be at least 6.3 mm (1/4 inch) if short circuiting or grounding of such terminals can result from projecting strands of wire. For circuits involving no potential greater than 50 V rms AC or DC, spacings at field wiring terminals may be 3.0 mm (1/8 inch) through air and 6.3 mm (1/4 inch) over surface.						
[b] For the purpose of this requirement, a metal piece attached to the enclosure is considered to be a part of the enclosure if deformation of the enclosure is likely to reduce the spacings between the metal piece and uninsulated live parts.						

Table 2
Full-load motor-running currents in amperes corresponding to various AC kilowatt and horsepower ratings

(See 6.4.1, 6.14.1, 7.10.5, 11.7.1, and 15.1)

Rated operational power kW[d] hp[e]		Guide values of rated operational currents at										
		110 – 120V	200V	208V	230V	220 – 240V[a]	380 – 415V[b,c]	400V	440 – 480V	500 V	550 – 600V	690 V
kW	hp	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase
0.06	–	–	–	–	0.35	–	–	0.20	–	0.16	–	0.12
0.9	–	–	–	–	0.52	–	–	0.30	–	0.24	–	0.17
0.12	–	–	–	–	0.70	–	–	0.44	–	0.32	–	0.28
0.18	–	–	–	–	1.0	–	–	0.60	–	0.48	–	0.35
0.25	–	–	–	–	1.5	–	–	0.85	–	0.68	–	0.49
0.37	–	–	–	–	1.9	–	–	1.10	–	0.88	–	0.64
–	1/2	4.4	2.5	2.4	–	2.2	1.3	–	1.1	–	0.9	–
0.55	–	–	–	–	2.6	–	–	1.5	–	1.2	–	0.87
–	3/4	6.4	3.7	3.5	–	3.2	1.9	–	1.6	–	1.3	–
–	1	8.4	4.8	4.6	–	4.2	2.5	–	2.1	–	1.7	–
0.75	–	–	–	–	3.3	–	–	1.9	–	1.5	–	1.1
1.1	–	–	–	–	4.7	–	–	2.7	–	2.2	–	1.6
–	1-1/2	12.0	6.9	6.6	–	6.0	3.6	–	3.0	–	2.4	–
–	2	13.6	7.8	7.5	–	6.8	4.1	–	3.4	–	2.7	–
1.5	–	–	–	–	6.3	–	–	3.6	–	2.9	–	2.1
2.2	–	–	–	–	8.5	–	–	4.9	–	3.9	–	2.8
–	3	19.2	11.0	10.6	–	9.6	5.8	–	4.8	–	3.9	–
3.0	–	–	–	–	11.3	–	–	6.5	–	5.2	–	3.8
4	–	–	–	–	15	–	–	8.5	–	6.8	–	4.9
–	5	30.4	17.5	16.7	–	15.2	9.2	–	7.6	–	6.1	–
5.5	–	–	–	–	20	–	–	11.5	–	9.2	–	6.7
–	7-1/2	44.0	25.3	24.2	–	22.0	13.3	–	11.0	–	9.0	-
–	10	56.0	32.2	30.8	–	28.0	16.9	–	14.0	–	11.0	–
7.5	–	–	–	–	27	–	–	15.5	–	12.4	–	8.9
11	–	–	–	–	38.0	–	–	22.0	–	17.6	–	12.8

Table 2 Continued on Next Page

Table 2 Continued

Rated operational power kW[d] hp[e]		Guide values of rated operational currents at										
		110 – 120V	200V	208V	230V	220 – 240V[a]	380 – 415V[b,c]	400V	440 – 480V	500 V	550 – 600V	690 V
kW	hp	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase
–	15	84	48.3	46.2	–	42.0	25.4	–	21.0	–	17.0	–
–	20	108	62.1	59.4	–	54.0	32.7	–	27.0	–	22.0	–
15	–	–	–	–	51	–	–	29	–	23	–	17
18.5	–	–	–	–	61	–	–	35	–	28	–	21
–	25	136	78.2	74.8	–	68	41.1	–	34	–	27	–
22	–	–	–	–	72	–	–	41	–	33	–	24
–	30	160	92	88	–	80	48.4	–	40	–	32	–
–	40	208	120	114	–	104	62.9	–	52	–	41	–
30	–	–	–	–	96	–	–	55	–	44	–	32
37	–	–	–	–	115	–	–	66	–	53	–	39
–	50	260	150	143	–	130	78.7	–	65	–	52	–
–	60	–	177	169	–	154	93.2	–	77.0	–	62.0	–
45	–	–	–	–	140	–	–	80	–	64	–	47
55	–	–	–	–	169	–	–	97	–	78	–	57
–	75	–	221	221	–	192	116	–	96	–	77	–
–	100	–	285	273	–	248	150	–	124	–	99	–
75	–	–	–	–	230	–	–	132	–	106	–	77
90	–	–	–	–	278	–	–	160	–	128	–	93
–	125	–	359	343	–	312	189	–	156	–	125	–
110	–	–	–	–	340	–	–	195	–	156	–	113
–	150	–	414	396	–	360	218	–	180	–	144	–
132	–	–	–	–	400	–	–	230	–	184	–	134
–	200	–	552	528	–	480	290	–	240	–	192	–
150	–	–	–	–	–	–	–	–	–	–	–	–
160	–	–	–	–	487	–	–	280	–	224	–	162
185	–	–	–	–	–	–	–	–	–	–	–	–
–	250	–	–	–	–	604	365	–	302	–	242	–
200	–	–	–	–	609	–	–	350	–	280	–	203
220	–	–	–	–	–	–	–	–	–	–	–	–
–	300	–	–	–	–	722	437	–	361	–	289	–
250	–	–	–	–	748	–	–	430	–	344	–	250
280	–	–	–	–	–	–	–	–	–	–	–	–
–	350	–	–	–	–	828	501	–	414	–	336	–
–	400	–	–	–	–	954	577	–	477	–	382	–
300	–	–	–	–	–	–	–	–	–	–	–	–
315	–	–	–	–	940	–	–	540	–	432	–	313
–	450	–	–	–	–	1,030	623	–	515	–	412	–
335	–	–	–	–	–	–	–	–	–	–	–	–
355	–	–	–	–	1,061	–	–	610	–	488	–	354
–	500	–	–	–	–	1,180	714	–	590	–	472	–
375	–	–	–	–	–	–	–	–	–	–	–	–

Table 2 Continued on Next Page

Table 2 Continued

Rated operational power kW[d] hp[e]		Guide values of rated operational currents at										
		110 – 120V	200V	208V	230V	220 – 240V[a]	380 – 415V[b,c]	400V	440 – 480V	500 V	550 – 600V	690 V
kW	hp	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase	3 phase
400	–	–	–	–	1,200	–	–	690	–	552	–	400
425	–	–	–	–	–	–	–	–	–	–	–	–
450	–	–	–	–	–	–	–	–	–	–	–	–
475	–	–	–	–	–	–	–	–	–	–	–	–
500	–	–	–	–	1,478	–	–	850	–	680	–	493
530	–	–	–	–	–	–	–	–	–	–	–	–
560	–	–	–	–	1,652	–	–	950	–	760	–	551
600	–	–	–	–	–	–	–	–	–	–	–	–
630	–	–	–	–	1,844	–	–	1,060	–	848	–	615
670	–	–	–	–	–	–	–	–	–	–	–	–
710	–	–	–	–	2,070	–	–	1,190	–	952	–	690
750	–	–	–	–	–	–	–	–	–	–	–	–
800	–	–	–	–	2,340	–	–	1,346	–	1,076	–	780
850	–	–	–	–	–	–	–	–	–	–	–	–
900	–	–	–	–	2,640	–	–	1,518	–	1,214	–	880
950	–	–	–	–	–	–	–	–	–	–	–	–
1,000	–	–	–	–	2,910	–	–	1,673	–	1,339	–	970

[a] To obtain full-load currents for 265 and 277 V motors, decrease corresponding 220 – 240 V ratings by 13 and 17 percent, respectively.

[b] These voltages are not used in North America, and are provided for reference only.

[c] Current values shown are applicable for NEMA Design B motors with starting codes F and G only. For all other motors further investigation is required.

[d] Preferred rated values according to item 39 in Annex A.

[e] Horsepower and currents values according to item 9 in Annex A, (60 Hz).

Table 3
Full-load motor-running currents in amperes corresponding to various AC kilowatt and horsepower ratings

(See 6.4.1, 6.14.1, 7.10.5, 11.7.1, and 15.1)

Rated operational power kW[d] hp[e]		Guide values of rated operational currents at										
		110 – 120V	200V	208V	230V	220 – 240V[a]	380 – 415V[b,c]	400V	440 – 480V	500 V	550 – 600V	690 V
kW	hp	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase
0.06	–	–	–	–	–	–	–	–	–	–	–	–
0.9	–	–	–	–	–	–	–	–	–	–	–	–
0.12	–	–	–	–	–	–	–	–	–	–	–	–
0.18	–	–	–	–	–	–	–	–	–	–	–	–
0.25	–	–	–	–	–	–	–	–	–	–	–	–
0.37	–	–	–	–	–	–	–	–	–	–	–	–

Table 3 Continued on Next Page

Table 3 Continued

Rated operational power kW[d] hp[e]		Guide values of rated operational currents at										
		110 – 120V	200V	208V	230V	220 – 240V[a]	380 – 415V[b,c]	400V	440 – 480V	500 V	550 – 600V	690 V
kW	hp	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase	1 phase
–	1/2	9.8	5.6	5.4	–	4.9	3.0	–	2.5	–	2.0	–
0.55	–	–	–	–	–	–	–	–	–	–	–	–
–	3/4	13.8	7.9	7.6	–	6.9	4.2	–	3.5	–	2.8	–
–	1	16.0	9.2	8.8	–	8.0	4.8	–	4.0	–	3.2	–
0.75	–	–	–	–	–	–	–	–	–	–	–	–
1.1	–	–	–	–	–	–	–	–	–	–	–	–
–	1-1/2	20.0	11.5	11.0	–	10.0	6.1	–	5.0	–	4.0	–
–	2	24.0	13.8	13.2	–	12.0	7.3	–	6.0	–	4.8	–
1.5	–	–	–	–	–	–	–	–	–	–	–	–
2.2	–	–	–	–	–	–	–	–	–	–	–	–
–	3	34.0	19.6	18.7	–	17.0	10.3	–	8.5	–	6.8	–
3.0	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–
–	5	56.0	32.2	30.8	–	28.0	16.9	–	14.0	–	11.2	–
5.5	–	–	–	–	–	–	–	–	–	–	–	–
–	7-1/2	80.0	46.0	44.0	–	40.0	25.4	–	21.0	–	16.0	-
–	10	100.0	57.5	55.0	–	50.0	31.5	–	26.0	–	20.0	–
7.5	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–
–	15	135	–	–	–	68.0	41.1	–	34.0	–	27.0	–
–	20	–	–	–	–	88.0	53.2	–	44.0	–	35.0	–
15	–	–	–	–	–	–	–	–	–	–	–	–
18.5	–	–	–	–	–	–	–	–	–	–	–	–
–	25	–	–	–	–	110	66.6	–	55	–	44	–
22	–	–	–	–	–	–	–	–	–	–	–	–
–	30	–	–	–	–	136	82.3	–	68	–	54	–
–	40	–	–	–	–	176	106	–	88	–	70	–
30	–	–	–	–	–	–	–	–	–	–	–	–
37	–	–	–	–	–	–	–	–	–	–	–	–
–	50	–	–	–	–	216	131	–	108	–	86	–

[a] To obtain full-load currents for 265 and 277 V motors, decrease corresponding 220 – 240 V ratings by 13 and 17 percent, respectively.

[b] These voltages are not used in North America, and are provided for reference only.

[c] Current values shown are applicable for NEMA Design B motors with starting codes F and G only. For all other motors further investigation is required.

[d] Preferred rated values according to item 39 in Annex A.

[e] Horsepower and currents values according to the item 22 in Annex A, (60 Hz).

Table 4
Wire bending space at field wiring terminals[a]

(See 6.7.1)

Size of wire		Minimum bending space, terminal to wall, in mm and inches					
		Wires per terminal					
		1		2		3	
mm²	AWG or MCM	mm	in	mm	in	mm	in
2.1 – 5.3	14 – 10	–	–	–	–	–	–
8.4 – 13.3	8 – 6	38	1-1/2	–	–	–	–
21.2 – 26.7	4 – 3	51	2	–	–	–	–
33.6	2	64	2-1/2	–	–	–	–
42.4	1	76	3	–	–	–	–
53.5	1/0	127	5	127	5	178	7
67.4	2/0	152	6	152	6	191	7-1/2
85.0	3/0	178	7	178	7	203	8
107.2	4/0	178	7	178	7	216	8-1/2
127	250	203	8	203	8	229	9
152	300	254	10	254	10	279	11
177	350	305	12	305	12	330	13
203	400	305	12	305	12	356	14
253	500	305	12	305	12	381	15
304	600	356	14	406	16	457	18
355	700	356	14	406	16	508	20
380 – 405	750 – 800	457	18	483	19	559	22
456	900	457	18	483	19	610	24

[a] Equipment intended for installation in Canada may comply with reference item 20 in Annex A.

Table 5
Ampacity of insulated conductors for field wiring

(See 6.4.1, 7.1.4, and 7.10.14)

Wire size		60°C		75°C	
mm²	(AWG or kcmil)	Copper	Aluminum[a]	Copper	Aluminum[2,d]
0.20	(24)	2	–	–	–
0.32	(22)	3	–	–	–
0.52	(20)	5	–	–	–
0.82	(18)	7	–	–	–
1.3	(16)	10	–	–	–
2.1	(14)	15	–	15	–
3.3	(12)	20	15	20	15
5.3	(10)	30	25	30	25
8.4	(8)	40	30	50/45[b]	40/30[b]
13.3	(6)	55	40	65	50

Table 5 Continued on Next Page

Table 5 Continued

Wire size		60°C		75°C	
mm^2	(AWG or kcmil)	Copper	Aluminum[a]	Copper	Aluminum[2,d]
21.2	(4)	70	55	85	65
26.7	(3)	80	65	100	75
33.6	(2)	95/100[b]	75	115	90
42.4	(1)	110[a]	85[a]	130	100
53.5	(1/0)	–	–	150	120
67.4	(2/0)	–	–	175	135
85.0	(3/0)	–	–	200	155
107	(4/0)	–	–	230	180
127	(250)	–	–	255	205
152	(300)	–	–	285	230
177	(350)	–	–	310	250
203	(400)	–	–	335	270
253	(500)	–	–	380	310
304	(600)	–	–	420	340
355	(700)	–	–	460	375
380	(750)	–	–	475	385
405	(800)	–	–	490	395
456	(900)	–	–	520	425
506	(1,000)	–	–	545	445
633	(1,250)	–	–	590	485
760	(1,500)	–	–	625	520
887	(1,750)	–	–	650	545
1 010	(2,000)	–	–	665	560

NOTES

1 For a multiple conductor connector at a terminal, the value shall be multiplied by the number of conductors that the terminal will accommodate 53.5 mm^2 (1/0 AWG) or larger.

2 These values of ampacity apply only if not more than three conductors will be field-installed in the conduit. If four or more conductors, other than a neutral that carries the unbalanced current, will be installed in a conduit (as can occur because of the number of conduit hubs provided in an outdoor motor control centre because of the number of wires necessary in certain polyphase systems, or other reasons) the ampacity of each of those conductors is 80% of the value given in the table if 4 – 6 conductors are involved, 70% of that value if 7 – 24 conductors, 60% of that value if 25 – 42 conductors, and 50% of that value if 43 or more conductors.

[a] If the motor control centre is marked to indicate that 75°C (167°F) wire shall be used at the terminal, the acceptable current is 130 A for a copper conductor and 100 A for an aluminum conductor.

[b] Differences are from item 2 in Annex A.

[c] See product standard for specific application.

[d] Item 2 in Annex A requires copper conductors only for fire pump service.

Table 6
Standard short circuit test values

(See 7.1.7)

Rating,		Test current, amperes[a]	Power factor
kW	Horsepower		
0 – 0.7	0 – 1[b]	1,000	0.70 – 0.80
1.1 – 37.3	1.5 – 50	5,000	0.70 – 0.80
39 – 149	51 – 200	10,000	0.70 – 0.80
150 – 298	201 – 400	18,000	0.25 – 0.30
299 – 447	401 – 600	30,000	0.20 or less
448 – 671	601 – 900	42,000	0.20 or less
672 – 1193	901 – 1600	85,000	0.20 or less

[a] Symmetrical rms amperes.

[b] At 300 V or less.

Table 7
Size of bonding, equipment grounding, grounding electrode conductors, and ground bus[a]

(See 6.5.4 and 6.5.5)

Maximum ampere rating[b]	Size of equipment grounding or bonding conductor, minimum mm² (AWG or kcmil)[g]		Size of grounding electrode conductor, minimum mm² (AWG or kcmil)		Size of main bonding jumper, minimum mm² (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum[f]	Copper	Aluminum[f]
15	2.1[c] (14[c])	3.3[c] (12[c])	–	–	–	–
20	[2.1][g] 3.3[c] ([14][g] 12[c])	[3.3][g] 5.3[c] ([12][g] 10[c])	–	–	–	–
30	[3.3][g] 5.3[c] ([12][g] 10[c])	[5.3][g] 8.4[c] ([10][g] 8[c])	–	–	–	–
40	5.3[c] (10[c])	8.4[c] (8[c])	–	–	–	–
60	5.3[c] (10[c])	8.4[c] (8[c])	–	–	–	–
90	8.4 (8)	13.3 (6)	8.4 (8)	13.3 (6)	8.4 (8)	13.3 (6)
100	8.4 (8)	13.3 (6)	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)
150	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)	13.3 (6)	21.2 (4)
200	13.3 (6)	21.2 (4)	21.2 (4)	33.6 (2)	21.2 (4)	33.6 (2)
300	21.2 (4)	33.6 (2)	33.6 (2)	53.5 (1/0)	33.6 (2)	53.5 (1/0)
400	26.7 (3)	42.4 (1)	53.5[d] (1/0[d])	85[d] (3/0[d])	53.5[d] (1/0[d])	85[d] (3/0[d])
500	33.6 (2)	53.5 (1/0)	53.5 (1/0)	85 (3/0)	53.5 (1/0)	85 (3/0)
600	42.4 (1)	67.4 (2/0)	67.4 (2/0)	107 (4/0)	67.4 (2/0)	107 (4/0)
800	53.5 (1/0)	85 (3/0)	67.4 (2/0)	107 (4/0)	67.4 (2/0)	107 (4/0)
1000	67.4 (2/0)	107 (4/0)	85 (3/0)	127 (250)	85 (3/0)	127 (250)
1200	85 (3/0)	127 (250)	85 (3/0)	127 (250)	127[e] (250[e])	127 (250)
1600	107 (4/0)	177 (350)	85 (3/0)	127 (250)	152[e] (300[e])	203[e] (400[e])
2000	127 (250)	203 (400)	85 (3/0)	127 (250)	203[e] (400[e])	253[e] (500[e])

Table 7 Continued on Next Page

Table 7 Continued

Maximum ampere rating[b]	Size of equipment grounding or bonding conductor, minimum mm² (AWG or kcmil)[g]		Size of grounding electrode conductor, minimum mm² (AWG or kcmil)		Size of main bonding jumper, minimum mm² (AWG or kcmil)	
	Copper	Aluminum	Copper	Aluminum[f]	Copper	Aluminum[f]
2500	177 (350)	[253][g] 304 ([500][g] 600)	85 (3/0)	127 (250)	253[e] (500[e])	355[e] (700[e])
3000	203 (400)	304 (600)	85 (3/0)	127 (250)	304[e] (600[e])	380[e] (750[e])
4000	253 (500)	405 (800)	85 (3/0)	127 (250)	380[e] (750[e])	507[e] (1000[e])
5000	355 (700)	[507][g] 608 ([1000][g] 1200)	85 (3/0)	127 (250)	456 (900)	633 (1250)
6000	405 (800)	[633][g] 608 ([1250][g] 1200)	85 (3/0)	127 (250)	633 (1250)	760 (1500)

[a] See Table 8 for equivalent area of bus. Size of ground bus shall be in accordance with Table 8 based on columns 1 – 3 of Table 7.

[b] Maximum ampere rating of centre or circuit overcurrent device ahead of equipment-grounding means.

[c] In Mexico and the United States, values are applicable to equipment-grounding conductors only. (NOTE c does not apply in Canada.)

[d] If the ampere rating is 400 and the wire terminal connectors for the main service conductors are rated for two 85 mm² (3/0 AWG) copper conductors or two 127 mm² (250 kcmil) aluminum conductors but will not accept a 304 mm² (600 kcmil) conductor, these values may be reduced to 33.6 mm² (2 AWG) copper or 53.5 mm² (1/0 AWG) aluminum.

[e] The cross-section may be reduced to 12.5% of the total cross-section of the largest main service conductor of the same material (copper or aluminum) for any phase on centres rated 1200 A and over. This applies when the cross-section of the service conductors is limited by the wire terminal connectors provided.

[f] Aluminum is not permitted in Canada.

[g] In Canada, the values in brackets [xx] apply.

Table 8
Equivalent cross-sectional areas

(See Table 7)

Wire size mm²	Minimum cross-section	
(AWG or kcmil)	mm²	(in²)
2.1 (14)	2.08	(0.003)
3.3 (12)	3.31	(0.005)
5.3 (10)	5.26	(0.008)
8.4 (8)	8.39	(0.013)
13.3 (6)	13.55	(0.021)
21.2 (4)	21.29	(0.033)
26.7 (3)	26.45	(0.041)
33.6 (2)	33.55	(0.052)
42.4 (1)	42.58	(0.066)
53.5 (1/0)	53.55	(0.083)
67.4 (2/0)	67.74	(0.105)
85 (3/0)	85.16	(0.132)
107 (4/0)	107.10	(0.166)
127 (250)	126.45	(0.196)

Table 8 Continued on Next Page

Table 8 Continued

Wire size mm^2	Minimum cross-section	
(AWG or kcmil)	mm^2	(in^2)
152 (300)	152.26	(0.236)
177 (350)	177.42	(0.275)
203 (400)	202.58	(0.314)
253 (500)	253.55	(0.393)
304 (600)	304.0	(0.471)
355 (700)	354.84	(0.550)
380 (750)	380.00	(0.589)
405 (800)	405.16	(0.628)
507 (1000)	506.45	(0.785)
608 (1200)	607.73	(0.942)
633 (1250)	632.90	(0.981)
760 (1500)	760.00	(1.178)
887 (1750)	887.00	(1.374)
1010 (2000)	1013.00	(3.100)

Table 9
Ampacities of insulated conductors used within enclosures

(See 6.8.3)

Conductor size			Conductor size		
AWG or kcmil	(mm^2)	Ampacity	AWG or kcmil	(mm^2)	Ampacity
18	(0.82)	7	3/0	(85.0)	260
16	(1.3)	10	4/0	(107.2)	300
14	(2.1)	20	250	(127)	340
12	(3.3)	25	300	(152)	375
10	(5.3)	40	350	(177)	420
8	(8.4)	60	400	(203)	455
6	(13.3)	80	500	(253)	515
4	(21.2)	105	600	(304)	575
3	(26.7)	120	700	(354)	630
2	(33.6)	140	750	(380)	655
1	(42.4)	165	800	(406)	680
1/0	(53.5)	195	1000	(508)	780
2/0	(67.4)	225			

NOTES

1 For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in the table for that conductor multiplied by the number of conductors that the terminal will accommodate.

2 These values of ampacity apply only if not more than three conductors are field-installed in the conduit. If four or more conductors, other than a neutral that carries the unbalanced current, are installed in a conduit (as can occur because of the number of conduit hubs provided in outdoor equipment, the number of wires necessary in certain polyphase systems, or other reasons), the ampacity of each of the conductors is: 80 percent of these values if 4 – 6 conductors are involved, 70 percent of these values if 7 – 24 conductors are involved, 60 percent of these values if 25 – 42 conductors are involved, and 50 percent of these values if 43 or more conductors are involved.

Table 10
Recommended high fault short circuit ratings

(See 7.1.8)

High fault short circuit ratings[a]		
10,000	25,000	65,000
14,000	30,000	85,000
18,000	35,000	100,000
20,000	42,000	125,000
22,000	50,000	150,000
–	–	200,000

[a] Symmetrical rms amperes.

Table 11
Minimum spacings between traces of opposite polarity on printed wiring boards

(See 6.2.2)

Volts,[a] rms or DC	Transient voltage no limited		Transient voltage limited[b]	
	Coated[c] mm	Uncoated mm	Coated[c] mm	Uncoated mm
10	0.08	0.4	0.025	0.04
12.5	0.09	0.42	0.025	0.04
16	0.1	0.45	0.025	0.04
20	0.11	0.48	0.025	0.04
25	0.125	0.5	0.025	0.04
32	0.14	0.53	0.025	0.04
40	0.16	0.8	0.025	0.04
50	0.18	0.85	0.025	0.04
100	0.25	1.0	0.1	0.16
125	0.28	1.05	0.16	0.25
160	0.32	1.1	0.24	0.4
200	0.42	1.4	0.40	0.63
250	0.56	1.8	0.56	1.0
320	0.75	2.2	0.75	1.6
400	1.0	2.8	1.0	2.0
500	1.3	3.6	1.3	2.5
630	1.8	4.5	1.8	3.2
800	2.4	5.6	2.4	4.0
1,000	3.2	7.1	3.2	5.0
1,250	4.2	9.0	–	–
1,600	5.6	11.0	–	–
2,000	7.5	14.0	–	–
2,500	10.0	18.0	–	–
3,200	12.5	22.0	–	–
4,000	16.0	28.0	–	–
5,000	20.0	36.0	–	–

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Table 11 Continued

Volts,[a] rms or DC	Transient voltage no limited		Transient voltage limited[b]	
	Coated[c] mm	Uncoated mm	Coated[c] mm	Uncoated mm
6,300	25.0	45.0	–	–
8,000	32.0	56.0	–	–

Note:

Linear interpolation of values is permitted.

[a] Between the traces where spacing is measured.

[b] The maximum recurring peak voltage shall not exceed the applicable value specified in Table 6.3 in accordance with item 37 in Annex A, when tested in accordance with the Recurring Peak Voltage Determination Test, in accordance with item 37 in Annex A, Section 9, except a coated printed wiring board shall be tested in the uncoated condition.

[c] The coating shall comply with the requirements of Clause 7.12.

Table 12
Test voltages for verifying clearances

(See 7.9.3)

Specified minimum through-air spacing, mm	Test voltages for use at a 2000 m elevation, kV[a]	
	AC impulse, AC peak, or DC	AC rms
0.4	1.5	1.1
0.8	1.9	1.3
1.6	2.7	1.9
2.4	3.5	2.5
3.2	4.3	3.0
4.8	5.6	4.0
6.4	6.8	4.8
9.5	8.8	6.3
12.7	11.2	7.9

[a] See Table 13 for other elevations.

Table 13
Test voltages for verifying clearances at altitudes other than 2000 m

(See 7.9.3 and Table 12)

Specified minimum through-air spacing, mm	Test voltages, kV							
	AC impulse, AC peak, or DC				AC rms			
	Altitude, m				Altitude, m			
	Sea level	200	500	1000	Sea level	200	500	1000
0.4	1.7	1.7	1.7	1.6	1.2	1.2	1.2	1.2
0.8	2.2	2.1	2.1	2.0	1.5	1.5	1.5	1.4
1.6	3.3	3.3	3.2	3.0	2.4	2.3	2.3	2.1
2.4	4.4	4.3	4.1	3.9	3.1	3.0	2.9	2.8

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